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A High-Frequency Analysis of Euro Area Monetary Policy

Unveiling the Dynamics During the Covid-19 Pandemic and Beyond (2020-2023)

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This master thesis is written as part of the Master of Science program at the Norwegian School of Economics, and constitutes 30 ECTS of the study. Thus, the thesis marks the culmination of our MSc degree within the economics profile.

While the process has been time-consuming and occasionally challenging, the overall experience has been exceptionally fulfilling. Our understanding of monetary policy analysis has expanded, sparking a deeper interest in the broader field of economic policy. We have also immersed ourselves into a range of different programming languages for conducting our analysis, knowledge which is sure to constitute a useful set of skills for our future career.

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Abstract

In this master thesis, we investigate the effects of monetary policy surprises in the euro area on key financial indicators from 2020 to 2023, a period marked by the Covid-19 pandemic and other global crises.

Our methodology follows that of Altavilla et al. (2019); we first identify factors related to the European Central Bank's communication strategy, including the Target factor, Timing, Forward Guidance (FG), and Quantitative Easing (QE). Using the Euro Area Monetary Policy Event-Study Database (EA-MPD), we analyze intraday changes in financial variables against European Central Bank (ECB) policy announcements, employing a high-frequency event study to assess the causal impact of these surprises. Finally, we examine information effects by looking at reactions to monetary policy in the stock market.

Our findings are mainly consistent with those of Altavilla et al. (2019) for the 2002-2018 period. However, in extending our analysis to 2023 we find marked differences. Firstly, we identify a smaller-than-expected effect of the Target factor on Overnight Index Swap (OIS) yields during the 2020-2023 period, indicating market anticipations to interest rate changes. Secondly, we find a larger impact of the Timing factor during the period of interest, indicating a substantial revision of expectations regarding upcoming monetary decisions. Thirdly, our estimates show that the Quantitative Easing factor significantly influenced key indexes like the Euro Stoxx 50 (STOXX50E) and the Euro Area Bank Stock Market Sub-Index (SX7E), diverging from previous findings and reflecting the period's extensive fiscal and monetary policies. Finally, our analysis reveals that the market's response to policy actions during the period in question was predominantly influenced by Odyssean surprises, rather than providing new insights into the economic outlook. This is a notable observation, as it deviates from the usual expectations of increased informational impacts during crises. Typically, one would anticipate a greater prevalence of Delphic surprises in such scenarios, but our findings suggest otherwise.

Future research could enhance this analysis through a VAR approach, focusing on policy surprises as external instruments to further explore uncertainty and information effects in monetary policy.

Keywords – European Central Bank, Monetary Policy, High Frequency Identification.

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1 Introduction

The Eurpean Central Bank's unique approach of announcing monetary policy in two separate time windows, unlike other big monetary authorities, highlights the need for more focused research on the euro area transmission mechanism. Our research stands out by examining the entire span of the Covid-19 pandemic and its aftermath, rather than limiting to the pre-pandemic era or the initial phase of the pandemic as most existing studies do. This broader scope allows us to provide fresh insights into the role of euro area monetary policy during this critical time.

The motivation for our study stems from the multitude of monetary policy decisions made during this relatively short period of time. We aim to understand if the frequency and scale of these decisions have caused more significant surprises in the financial markets and among its participants. Additionally, we question whether the findings of a previous study for the 2002-2018 period by Altavilla et al. (2019) remain relevant in the context of the unique and unprecedented events between 2020 and 2023.

Our investigation is further motivated by the intriguing question of which type of surprises, Odyssean or Delphic, has been dominant during this specific timeframe. This adds an additional level of depth to our analysis, providing insights crucial for understanding the signaling effects of monetary policy.

1.1 Motivation

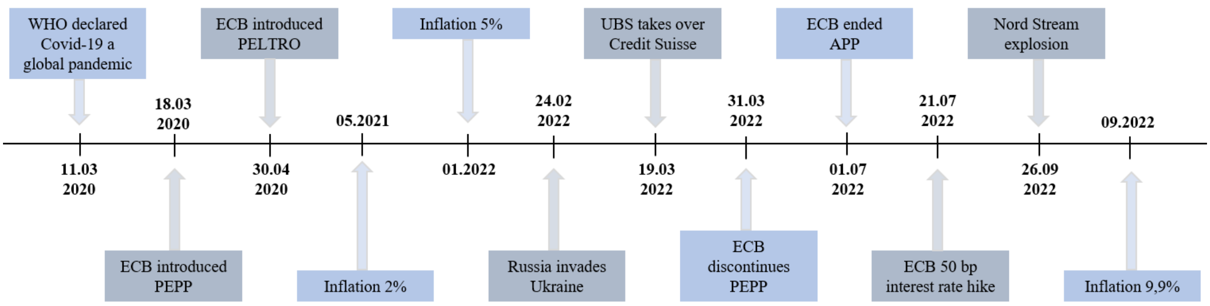
The last few decades have unfolded a captivating saga for monetary policy, defined by a series of extraordinary events that have profoundly shaped the global economic landscape. The aftermath of the global financial crisis and the ensuing sovereign debt crisis compelled central banks worldwide to adopt unconventional measures, including aggressive quantitative easing programs. The prolonged period of low-interest rates, coupled with unconventional monetary policies, forged a unique economic environment for the beginning of the 2020s decade.

The Covid-19 pandemic, along with its ramifications on monetary policy and the economic and monetary policy landscape, and events in the post-pandemic era, represent intriguing cases within the realm of monetary policy. Keeping interest rates at zero and introducing several quantitative easing programs in response to the Covid-19 outbreak, followed by extraordinary interest rate hikes amid rising inflation, concurrent energy crisis, and geopolitical tensions, creates a complex and dynamic backdrop for our research.

As illustrated in Figure 1.1 the last few years are characterized by a convergence of events that have seldom occurred so to say simultaneously, making it an intriguing and valuable extension of the work by Altavilla et al. (2019).

We find it fascinating to explore whether monetary policy decisions during the 2020-2023 period have loomed larger surprises and had more substantial impacts on financial markets than in the pre-pandemic era. The period under consideration commenced with an expansionary monetary policy with several quantitative easing measures but later shifted to a contractionary stance to counteract rising inflation towards the end. The notable shifts in monetary policy during this timeframe raise the question of whether we can discern significant outcomes, given the juxtaposition of these contrasting policy measures within a relatively short period of time. Moreover, the prevailing type of monetary policy surprise during this period remains unknown, adding significant value to its inclusion in our thesis.

Figure 1.1: Recent events



Note: Inflation[1], Non-regular open market operations[2], Pandemic[3], Credit Suisse[4], Invasion & Nord Stream[5], Interest rate hike[6]. *Source:* own elaboration

[1] Eurostat (2021, 2022a, 2022b)
[2] Includes PEPP, PELTRO and APP (European Central Bank, 2023g)
[3] Cucinotta and Vanelli (2020)
[4] Englundh (2023)
[5] Adomaitis (2022)
[6] European Central Bank (2023m)

In the subsequent section, we will delve into a comprehensive assessment of recent economic events in the euro area. This thorough assessment aims to furnish additional context and rationale, further highlighting the motivation and interest inherent in our thesis.

1.2 Assessment of Recent Economic Developments

The Covid-19 pandemic and its aftermath have presented the global economy with a period of unprecedented challenges and complexities. Against this backdrop, examining the impact of monetary policy surprises from the European Central Bank (ECB) on various financial variables within the euro area, provides a unique opportunity to understand the dynamics of economic responses during extraordinary times. This section sets out to provide a background on recent developments in the euro area for a set of variables pertinent for monetary policy and economic development, contextualizing the significance of the 2020-2023 period and its implications for monetary policy surprises.

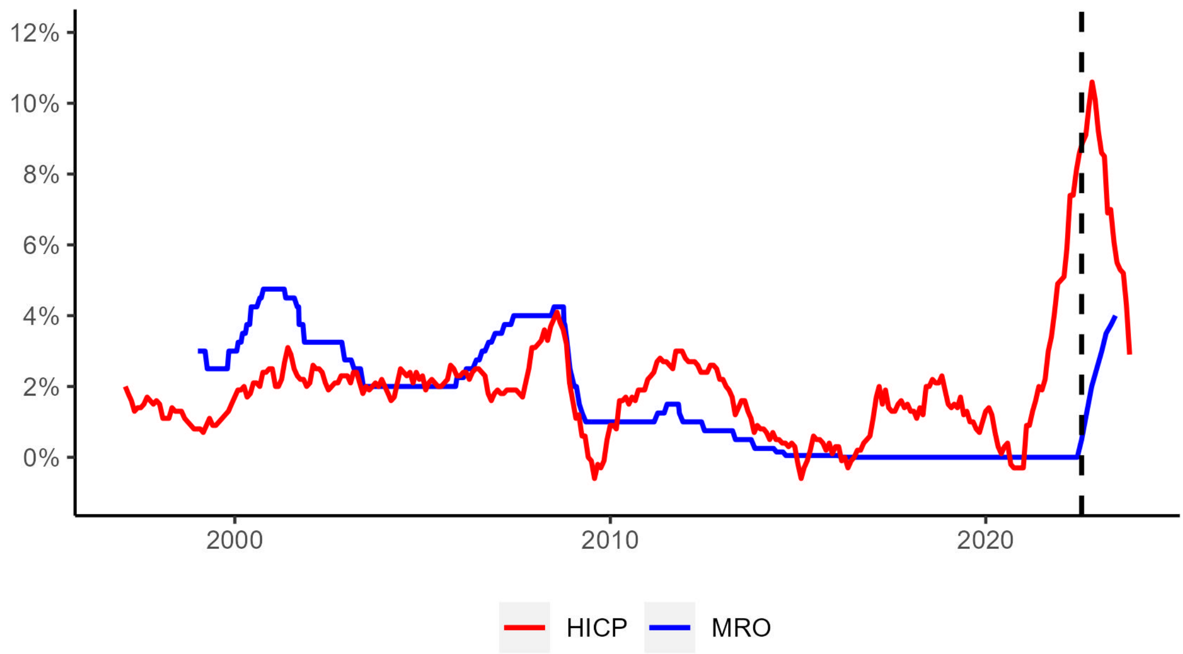
As delineated in Section 2.4.4, the ECB currently follows an inflation target of 2%, up from the earlier target "below but close to 2%". The aftermath of the 2008 financial crisis and the subsequent sovereign debt crisis in the euro area prompted the ECB to adopt forward guidance. Nevertheless, economic growth in the euro area faced challenges, and inflation persisted at low levels, prompting the ECB to lower interest rates.

According to Bobasu et al. (2021), the early stages of the Covid-19 pandemic saw a decline in consumer price inflation due to supply constraints and diminished demand. As illustrated in Figure 1.2, inflation witnessed a decline, even becoming slightly negative in the beginning of the Covid-19 pandemic. In response, the ECB swiftly adopted extraordinary pandemic quantitative easing measures (see Section 2.4.2 for detailed insights) to provide expansive monetary policy, aiming to avert serious deflationary risks and support the economy.

However, as the pandemic evolved and the supply side constraints continued, further expansionary monetary policy, together with fiscal policy measures, were implemented to increase demand and sustain economic activity in the euro area. According to Cascaldi-Garcia et al. (2022), the upward pressure on prices, which we see in Figure 1.2, was motivated by a series of interconnected factors. These include supply side constraints during the pandemic, the tight labor markets which fostered higher wage growth, strongly increasing house prices due to high levels of cash holdings among households as a result of the low interest rates and fiscal stimulus, and rising costs of energy.

What was initially perceived as a transitory phase of slightly elevated inflation levels, defied expectations becoming more prolonged and substantial than anticipated. The Russian invasion of Ukraine on February 24, 2022, further escalated inflation, driven by increased costs of food and energy (Arce et al., 2023). All of this prompted central bank actions to lower the inflationary pressures. On top of that, energy prices, particularly in Europe, soared after the Nord Stream pipeline explosion, contributing to elevated producer costs subsequently passed on to consumers (Gülenç, 2022).

Figure 1.2: Euro area inflation and the MRO rate.



Note: The graphs shows the development of the overall inflation in the euro area (HICP), together with the development in the interest rate on MRO's. The dashed black line is added to better visualize how high inflation in the euro area had become before the ECB increased the interest rate on marginal refinancing operations (MRO's). Data for the HICP graph is retrieved from the European Central Bank (2023n), while data for the graph of the interest rate on MRO's are retrieved from the replication files of Altavilla et al. (2019), specifically the Excel file 03events, and European Central Bank (2023f) for dates after September 13, 2018.

Since October 2016, the interest rate on MRO's has remained at 0% due to the persistent risk of deflation, as evident in Figure 1.2. While this prolonged low-rate policy is supportive of the economy, it presents challenges as conventional monetary policy effectiveness is constrained by the zero lower bound (ZLB). This is reflected in the unchanged interest rate on MRO's during the initial stages of the Covid-19 pandemic, and why ECB implemented more QE tools, such as PEPP, during the pandemic (see Section 2.4.2 for details on ECB policy tools).

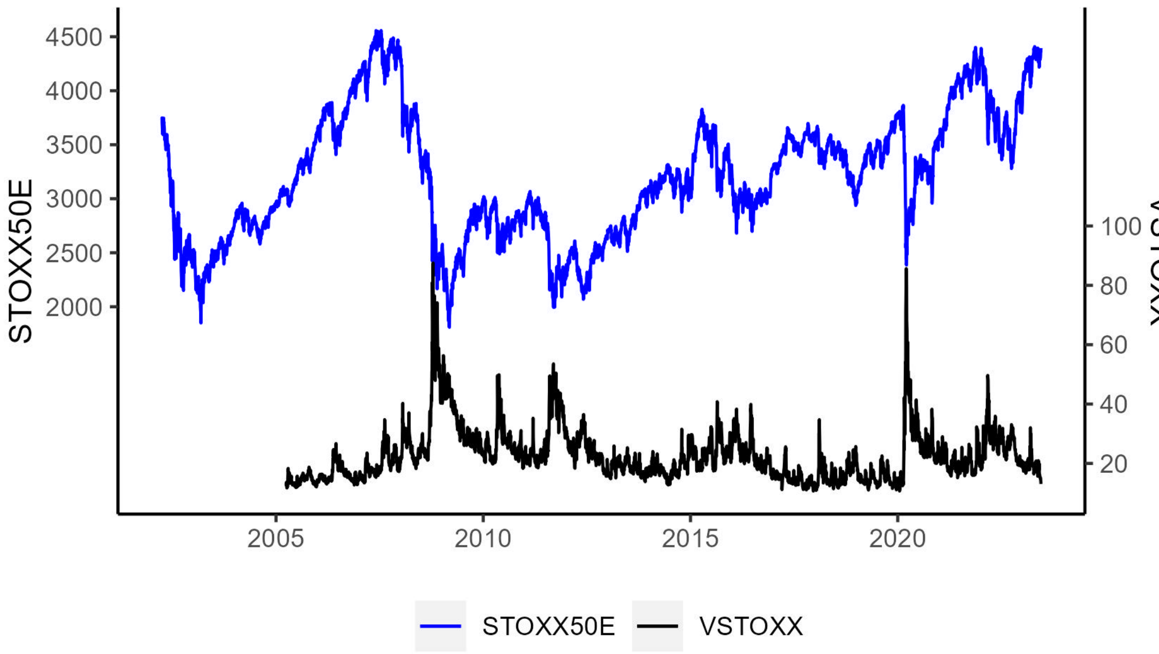
According to the European Central Bank (2023n), inflation reached 2% in May 2021 and soared to 5% in December of the same year. The ECB did not increase its interest rate on MRO's before July 2022 (European Central Bank, 2023m). As seen in Figure 1.2, inflation had already surpassed 8% by this time. One could argue that the ECB waited too long with its response to rising inflation levels; however, such assessments are clearer in hindsight. Because of the late response to the inflation levels that had become way too high, the interest rate on MRO's witnessed rapid increments, marked by multiple 50 and 75 basis point (bp) increases, as the ECB sought to mitigate inflationary pressures in the economy.

Over the past 15 years, two events have resulted in significantly heightened volatility; the 2008 financial crisis and the onset of the Covid-19 pandemic in 2020. This is evident in Figure 1.3, depicting the development of two indices — the Euro Stoxx 50 Index (STOXX50E), representing the 50 largest companies in the eurozone by market capitalization, and the Volatility Euro Stoxx 50 Index (VSTOXX), which displays the levels of volatility of the index across time by measuring the expected stock index movements in the upcoming 30 days. During both events, uncertainty levels reached approximately 85, significantly above the normal levels of uncertainty of 25 according to Dennison (2021).

Uncertainty is not something stock markets are especially fond of. Consequently, elevated uncertainty tends to amplify market volatility, resulting in stronger reactions to both positive and negative news (Megaritis et al., 2021). Megaritis et al. (2021) finds that the main driver of volatility in stock prices is heightened uncertainty about the future state of the economy, and to a lesser extent economic policy that is based on the macroeconomic conditions. From this perspective, one can attribute the dip in the STOXX50E index at the beginning of the pandemic to a sudden increase in uncertainty. Given the unknown consequences of the pandemic, this seems to be a plausible explanation.

Furthermore, the findings of Megaritis et al. (2021) can also provide an explanation for the fall in the STOXX50E index and increase in the VSTOXX index when inflation started to reach significant levels of 6-8% in the first half of 2022. This period witnessed the second-highest surge in the VSTOXX index since the onset of the pandemic, reaching a level of about 50 and declining as interest rate hikes commenced during the summer of 2022. This contributes to the perspective that it is uncertainty about future economic conditions, rather than uncertainty about the policy response, that triggers stock price volatility.

Figure 1.3: The development of the STOXX50E index and the volatility index VSTOXX.



Note: The graph shows the two index levels over time. Data used for constructing the graph is retrieved from Bloomberg.

1.3 Research Question

Based on our motivation, our thesis will be structured to address the following research question:

> *How have monetary policy surprises influenced financial market variables during and after the Covid-19 pandemic, and how do these impacts compare to pre-pandemic levels?*

To investigate this research question, we will employ a high-frequency identification approach for monetary policy surprises. These monetary policy surprises will be employed in an OLS regression to assess the effects from the surprises on a set financial variables.

1.4 Outline

The thesis is structured into six sections, including the Introductory Section. The remainder of the thesis proceeds as follows. In Section 2, we delve into the theoretical framework surrounding monetary policy. Building upon this foundation, Section 3 explores existing literature on high-frequency identification in monetary policy, as well as touching into other identification methods such as vector autoregression. Following this, Section 4 outlines the econometric framework employed in our thesis, together with the data used in our analysis. Moving forward, Section 5 showcases the results, accompanied by a comprehensive discussion. Finally, Section 6 encapsulates the thesis, offering conclusive remarks, and proposes new lines for future research concerning high-frequency identification in monetary policy.

2 Theoretical Framework

2.1 Monetary Policy

Monetary policy encompasses the actions undertaken by a country's central bank to influence the circulation of money in the economy and thereby also affecting other variables, such as borrowing costs (Friedman, 1995). The multifaceted nature of monetary policy involves a delicate interplay of factors, and a critical aspect in estimating effects from it pertains to addressing issues related to endogeneity. The endogeneity of monetary policy refers to the intricate relationship between policy actions and economic variables, and how these are linked together and affect each other (Nakamura & Steinsson, 2018a).

Furthermore, the effectiveness of monetary policy, and its impact on markets and the expectations of market participants, is intricately tied to the presence of information effects and lagging effects. Information effects refer to the influence of central bank communication and signals on market expectations and behavior (Nakamura & Steinsson, 2018a). As central banks communicate their policy intentions, market participants adjust their expectations, leading to shifts in asset prices and economic activities. This dynamic interplay introduces complexity into the transmission of monetary policy.

Moreover, monetary policy often exhibits lagging effects, wherein the complete impact of policy changes may not be immediately realized. This lag can be attributed to various channels through which monetary policy influences the economy, as depicted in Figure 2.2. Recognizing and comprehending these nuances are crucial for a comprehensive analysis of monetary policy, enabling a more nuanced evaluation of the dynamic relationship between policy actions and financial- and economic variables.

In the subsequent sections, we will delve deeper into these facets of monetary policy and explore how the ECB implements and executes its monetary policy in the euro area.

2.2 Endogeneity and its Role in Monetary Policy

Various factors contribute to endogeneity in economic models, including omitted variable bias, measurement error, simultaneity, and reverse causality (Sæthre, 2022). In the context of monetary policy literature, simultaneity, omitted variable bias, and reverse causality are particularly salient.

Analyzing how monetary policy affects the macroeconomy and financial markets is intricate due to the inherent two-way causal relationship. This challenge arises from the fact that changes in monetary policy, such as altering interest rates, can influence overall economic conditions and financial asset prices. Conversely, the state of the macroeconomy and the financial markets can also influence monetary policy through policymakers responding to factors like high inflation with tighter monetary measures or large decline in financial asset prices with more expansionary monetary policy. Hence, monetary policy, the macroeconomy, and financial asset prices are simultaneously determining each other.

The literature emphasizes the role of the central bank policy rate as the key policy instrument. Cloyne and Hürtgen (2016) argues that when assessing causality of monetary policy, we should focus on the effect of changes around the policy rate. By doing so, we will also be able to compare our findings to both existing and past literature, which did not take into account unconventional monetary policy measures such as quantitative easing or forward guidance.

As pointed out by Cloyne and Hürtgen (2016), failing to address the relationship between the policy rate changes and their effects in empirical models can lead to outcomes such as the "price puzzle". This price puzzle was first documented by Sims (1992); in conventional VAR models, prices and inflation puzzlingly increase following a monetary contraction. He argues that the puzzling results arose because the shocks used to identify causality also included the endogenous policy responses to inflation forecasts. Cloyne and Hürtgen (2016) outlines three primary challenges when identifying the effect of monetary policy:

1. Monetary policy tools like interest rates are set in a simultaneous manner and it is necessary to detach cyclical movements in interest rates from the deliberate changes in the policy rate by policymakers to avoid endogeneity problems.
2. Policymakers are inclined to respond to anticipated future economic conditions in

addition to the present and historical information. It is important to recreate a proxy for the information set on which the policy decisions were made.

3. Policymakers make decisions based on current, "real-time" data, whilst empirical research is often based on ex-post revised data. As shown by Orphanides (2001), this could affect estimates of the response of monetary policy.

Nakamura and Steinsson (2018b) notes that the possibly high number of factors influencing monetary policy decisions can lead to omitted variable bias in models estimating policy effects. Consequently, factors not being included or sufficiently well-proxied in models estimating monetary policy effects will cause an omitted variable bias.

When it comes to reverse causality in monetary policy, Karadi (2017) states that monetary policy decisions not only cause changes in other variables, but also can respond endogenously to changes in other variables. Problems related to reverse causality will be minimized if using the high-frequency identification approach. This because it is highly unlikely that variables related to the real economy, the financial sector, or anything else relevant for monetary policy will be affecting the monetary policy decision during the short time window around the announcements of monetary policy.

As evidenced in this section, various factors can contribute to endogeneity in monetary policy models. In the Literature Review section, we discuss the state-of-the-art specifications used in the literature to overcome the endogeneity problem in monetary policy. In the Empirical Methodology section we present the specification we employ in order to tackle our research question.

2.3 Information Effects From Monetary Policy

In theory, assuming the central bank and the public possess identical information should eliminate significant information effects resulting from central bank decisions and announcements.

However, the awareness of the public and the market participants that central banks, equipped with highly educated economists, might have an informational advantage—whether through possessing more information or being able to extract more from available market information—complicates this theoretical assumption. This perceived informational advantage, as emphasized by Janson and Jia (2020), prompts market participants to closely scrutinize central bank announcements and information, with any actions taken by the central bank being carefully observed and factored in by other market participants.

According to Nakamura and Steinsson (2018a), the impact on private sector views of non-monetary economic fundamentals resulting from Federal Open Market Committee (FOMC) announcements is termed "Fed information effects." These announcements, not only by the Fed but also by other central banks, have the potential to influence private sector views on various economic fundamentals and the trajectory of monetary policy. Consequently, they can induce significant effects in financial markets and shape reactions both during and after monetary policy announcements.

Campbell et al. (2012) proposes that central banks disclose private information when announcing monetary policy decisions, and that this results in the information effect. Consequently, a contractionary monetary surprise implies that the economic situation is better than expected. Financial market participants, in light of this unexpected information, may revise their forecasts upwards, leading to an increase in stock prices. Conversely, an expansionary monetary surprise would indicate a more adverse economic situation than anticipated. In response to this updated information, financial market participants downwardly adjust their forecasts, leading to a decline in stock prices.

Moreover, increased transparency from central banks, as highlighted by Janson and Jia (2020), contributes to the information effects stemming from central bank actions. Central banks often follow up interest rate decisions with statements outlining their views on economic fundamentals, influencing how market participants interpret these decisions. Janson and Jia (2020)'s findings indicate that market participants believe monetary policy conveys information about future output rather than inflation. Unexpected increases in the Fed funds rate, for instance, results in heightened expected output growth, while inflation expectations are minimally affected.

As pointed out by Jia (2023), such information effects from monetary policy can possibly create a policy dilemma for central banks. If the public assumes that central banks have superior knowledge about the state of the economy, it could offset the direct effects of interest rate changes in response to shocks. While central banks theoretically possess the means to provide the public with perfect information about the shocks affecting their interest rate decisions through direct communication, Jia (2023) argues that such an approach is suboptimal. Consequently, information effects persist in monetary policy.

As outlined in this section, the intricate dynamics of information effects in monetary policy, shaped by the perceived advantage of central banks in processing economic information, underscore the nuanced relationship between central bank actions and market responses. We present an empirical identification for information effects in the Empirical Methodology section, and discuss the presence of such effects in the period of interest (2020-2023) in the Results and Discussion section.

2.4 Monetary Policy in the Euro Area

In the following section we outline the functioning and key considerations of monetary policy in the euro area, mainly as presented by the European Central Bank (ECB) on their website (European Central Bank, 2023e).

2.4.1 Central Bank Independence

The significance of central bank independence in achieving the objective of price stability is underscored by the European Central Bank (2023c). As articulated by the European Central Bank (2023l), a wealth of empirical evidence and theoretical studies converge on the idea that an independent central bank is better equipped to maintain consistently low inflation rates, shielded from the influence of political pressures.

This viewpoint gains further credence from the insights provided by De Haan and Eijffinger (2016), who posits various theoretical grounds supporting central bank independence. One rationale is rooted in the potential inflationary consequences of political motivations to boost short-term output for electoral gains. Additionally, politicians might be tempted to leverage the central bank for increased money supply to fund government spending, thereby exerting inflationary pressures. Addressing the time-inconsistency problem of monetary policy, De Haan and Eijffinger (2016) contends that an independent and conservative central bank is more credible in adhering to established monetary policies, mitigating the risk of future deviations.

While the ECB, like most central banks, operates within defined policy goals, it possesses operational independence (European Central Bank, 2023l; Haldane, 2021). However, Benigno et al. (2023) highlights the absence of specific quantitative or qualitative goals in the Statute of the European System of Central Banks and the ECB. Consequently, the ECB is tasked with ensuring price stability, with the actual definition of price stability left to the determination of the ECB's Governing Council.

2.4.2 Monetary Policy Instruments

In pursuit of its primary goal of maintaining price stability, the European Central Bank (ECB) deploys a range of monetary policy instruments, as outlined by Roman (2023). The operational framework of the ECB and the national central banks of the euro area, as detailed by the European Central Bank (2023a), encompasses:

- **Open market operations**
  Open market operations, elucidated by the European Central Bank (2023g), serve to guide interest rates and, consequently, influence liquidity within the financial system. These operations also communicate the ECB's stance on monetary policy. Regular open market operations include main refinancing operations (MROs) and longer-term refinancing operations (LTROs), with respective durations of one week and three months. Non-regular operations over the past decade encompass pandemic emergency longer-term refinancing operations (PELTROs), targeted longer-term refinancing operations (TLTROs), asset purchase programme (APP), and pandemic emergency purchase programme (PEPP). The implementation of the APP was aimed at upholding the ECB's mandate for price stability and fortifying the monetary policy transmission mechanism, and has been the ECB's main quantitative easing (QE[1]) tool. The TLTROS are executed to offer appealing long-term funding of banks, thereby stimulating bank lending to the real economy, and enhancing the transmission of monetary policy. In response to the challenges posed by the Covid-19 pandemic, PELTROs were undertaken to infuse liquidity into the financial system and ensure the smooth functioning of the money market. The introduction of PEPP

[1]QE involves purchasing government and private sector bonds to inject more money into the economy to boost economic growth, employment and specially inflation such that deflation is avoided (European Parliament, 2015)

specifically aimed to reinforce the monetary policy transmission mechanism during this unprecedented global health crisis.

- **Standing facilities**

  The ECB provides two standing facilities for euro area credit institutions, detailed by the European Central Bank (2023h). The marginal lending facility grants access to overnight liquidity upon presentation of adequate eligible assets, while the deposit facility allows institutions to make overnight deposits with the central bank.

- **Minimum reserve requirements for credit institutions**

  As outlined by European Central Bank (2023j), credit institutions in the euro area are required by the ECB to hold a specified minimum amount of reserves with the relevant national central bank. The minimum reserve requirements are calculated as 1% of specified liabilities on the credit institutions balance sheets, primarily debt securities with maturities up to two years and customer deposits. If the minimum reserve requirements are not met, sanctions can be imposed by the ECB to the credit institutions not fulfilling the requirements.

- **Forward guidance**

  Utilizing forward guidance, as described by the European Central Bank (2023k), the ECB signifies the provision of information regarding its forthcoming monetary policy intentions grounded in its evaluation of the prospects for maintaining price stability. It is highly important that the forward guidance is grounded in, and consistent with the future economic outlook that the Governing Council of the ECB holds. This to be able to maintain credibility and thus being able to utilize forward guidance in the future. Forward guidance is especially useful when the conventional monetary policy tools, the key interest rates, are not very useful due to the zero lower bound (ZLB).[2]

When it comes to interest rates that the ECB sets, they have three main interest rates that the Governing Council of the ECB decides on every six weeks (European Central Bank, 2023d). These three interest rates are:

- The interest rate on the main refinancing operations (MRO).

[2]The ZLB refers to a situation where interest rates as set by a central bank have reached or are close to 0%.

- The interest rate on the deposit facility.
- The interest rate on the marginal lending facility (MLF).

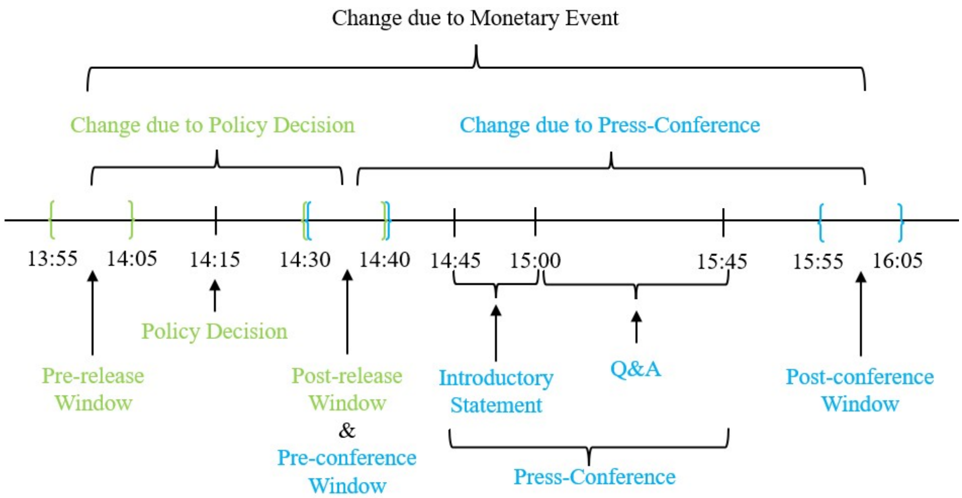
As highlighted by Roman (2023), the marginal rate on main refinancing operations is considered the ECB's primary interest rate, which the overnight money market interest rate fluctuates around. The other two interest rates, on the deposit facility and marginal lending facility establish the floor and the ceiling, respectively.

2.4.3 Decision-Making and Communication of the ECB

Concerning the decision-making process for monetary policy within the Eurosystem, the pivotal authority lies with the Governing Council, as highlighted by the European Central Bank (2023b). Comprising six members from the ECB's Executive Board and the governors of the euro area's 20 national central banks, the Governing Council holds the responsibility for major decisions. Since 2015, a rotational system governs voting rights, with Executive Board members exercising their right at each meeting, while the 20 national central bank governors take turns. This approach, necessitated by the Eurosystem's member state count, ensures the Governing Council's effective functioning by limiting voters per meeting. It is also worth mentioning that the five largest economies in the Eurosystem share four votes, while the other 15 member states share 11 voting rights. Of the 20 governors, 15 participate in each vote, leaving five governors without voting rights, creating a monthly rotation.

Furthermore, the Governing Council convenes biweekly, yet monetary policy decisions occur at six-week intervals, a practice adopted since 2015. As noted in Altavilla et al. (2019), from 1999 to late 2001, interest rate decisions were taken twice per month. Subsequently, from late 2001 to 2014, decisions occurred monthly. Since late 2001, press conferences have become a regular event after every monetary policy announcement, contrasting with the earlier practice of holding them every other announcement. The press conference commences with the president of the ECB reading an introductory statement, a document elucidating the rationale behind the selection of interest rates, outlining the ECB's perspective on the economic situation, and offering insights into its future actions. This segment spans approximately 15 minutes, succeeded by a 45 minute session dedicated to questions and answers (Q&A). Altavilla et al. (2019) argues that the distinct release of the policy decision and narrative information by the ECB distinguishes the disclosure of monetary policy information in the euro area from that of the Federal Reserve in the United States, where both occur simultaneously. Until July 21, 2022, press releases and conferences took place at 13:45 CET and 14:30 CET, respectively. Post that date, timings shifted to 14:15 CET and 14:45 CET for releases and conferences, respectively. The new timeline of the ECB policy communication is shown in Figure 2.1. As depicted in the picture, changes in financial variables taking place around the press release and the conference will be of help in constructing monetary policy surprises, as used by Altavilla et al. (2019) in their EA-MPD.

Figure 2.1: ECB policy communication timeline.



Note: Constructed based on information from the EA-MPD which Altavilla et al. (2019) have created.

2.4.4 Inflation Targeting

As previously noted, maintaining price stability stands as the ECB's primary objective. To anchor inflation expectations among market participants, the ECB introduced an inflation target in 1999, initially set in the medium term to be "below 2%" (Benigno et al., 2023). However, as outlined by Benigno et al. (2023), the ECB modified this target in 2003 to be "below but close to 2%." In 2021, the ECB once again revised its medium-term inflation target, establishing it at a flat 2%. This adjustment is deemed more reflective of the ECB's equal concern for inflation below and above the target, resulting in a notable shift in monetary analysts' long-term inflation expectations, with a higher percentage aligning with the 2% mark rather than below 2% (European Central Bank, 2022a).

As explained by European Central Bank (2022b), the choice of a 2% inflation target is strategic. It not only ensures price stability but also provides a buffer against deflation, a circumstance where monetary policy becomes less effective due to the effective lower bound (ELB).[3]

2.4.5 The Transmission Mechanism of Monetary Policy

Regarding the Transmission Mechanism of Monetary Policy, the European Central Bank (2023i) asserts that it delineates the process through which monetary policy decisions specifically influence the price level and, more broadly, the real economy. Within central banking, there is a widely embraced belief that the effects of monetary policy adjustments typically materialize as changes in inflation over a span of approximately 18 to 24 months. However, the paper by Mann (2023) challenges this conventional wisdom, particularly given the prevailing economic and policy landscape.

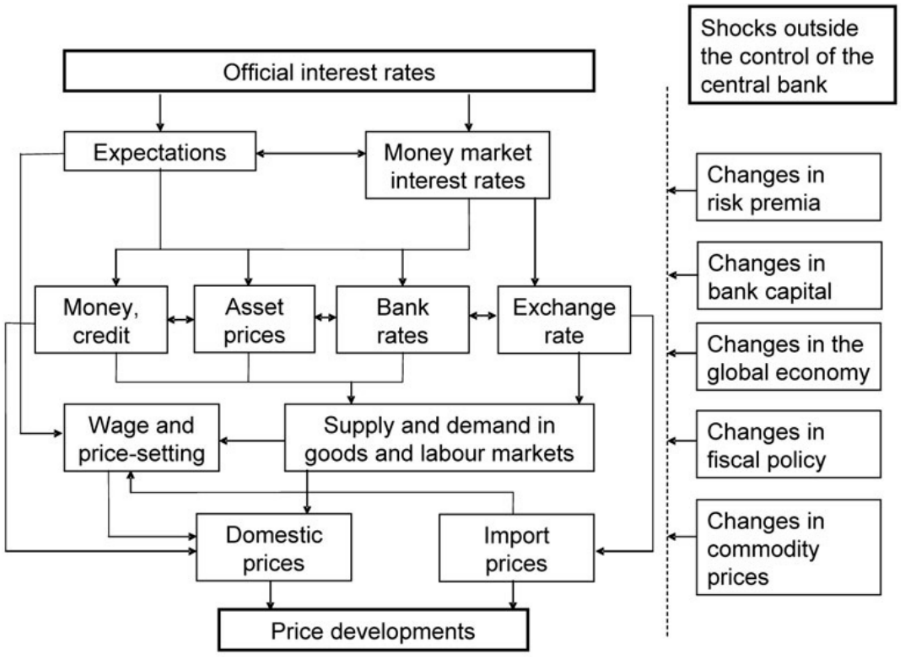
The dynamics of the monetary transmission mechanisms undergo transformations with shifts in the economy and its economic context. A pivotal question raised by Mann (2023) is whether the significant spikes in central banks policy rates observed over the past two years should have already produced a more pronounced impact on both the real economy and inflation.

Functioning of the transmission mechanism

Regarding the functioning of the transmission mechanism, as depicted in Figure 2.1 below, central banks rely on financial markets to convey policy decisions, aligning with their intended outcomes and public expectations. When the central bank adjusts its relevant interest rates, these changes are promptly reflected in money market interest rates, influencing bank lending and deposit rates (European Central Bank, 2023i). Households and businesses respond to altered financial conditions, interpreting them based on their expectations, thereby impacting economic output and price levels.

[3] The ELB, as defined by Banco de España (2023), represents a limit on the nominal interest rate set by the ECB, and other central banks as well. Setting the rate lower than this could jeopardize financial stability and negatively impact economic activity, credit supply, and inflation.

Figure 2.2: Transmission mechanism of monetary policy.



Note: Retrieved from European Central Bank (2023i).

As stated by the European Central Bank (2023i), the public's expectations concerning future interest rate changes extend their influence to medium- and longer-term interest rates. In addition, credibility allows the central bank to anchor inflation expectations, influencing and controlling expectations of future inflation, contributing to price stability. When this is the case, prices will be more stable and the inflation level will be lower.

Changes in the key interest rates that the central bank has, can influence more than just expectations and the interest rates in the money markets, as shown by Figure 2.1 above. Any effects that the changes in monetary policy might have on expectations and money market interest rates can further influence asset prices and the exchange rate (European Central Bank, 2023i). If asset prices increase due to changes in the ECB's interest rates, households owning such assets will become wealthier and therefore might be increasing their consumption. As a result of this, changes in asset prices can impact inflation indirectly by influencing the aggregated demand and supply in the economy. Exchange rate changes on the other hand, can directly influence the inflation, particularly affecting prices on imported goods, given that import goods are used for consumption. Indirectly the exchange rate can influence inflation, like asset prices, credit supply, and bank rates does, through affecting the supply and demand of goods and labor.

Moreover, the European Central Bank (2023i) points out that changes in the central bank interest rates affect bank rates due to the altered conditions in the money markets. If there is an interest rate increase, the incentives for households and businesses to take on loans to finance further consumption and investments will be reduced. At the same time, if there is an increase in the interest rates, credit institutions might reduce their supply of credit due to concerns of loan repayments. Thus, increased interest rates and reduced credit supply is likely to contribute to a reduction in households and businesses consumption and investments. The contrary would be the case if the central bank interest rates would be reduced.

According to Mann (2023), the speed at which the change in monetary policy transmits to the financial variables is not equal between the different financial variables, and it is not necessarily swift. Asset prices and the exchange rate are generally quickly affected, while the transmission to interest rates that consumers face (bank rates) and the credit supply may take more time, contributing to the observed time lag in monetary policy transmission to the real economy.

Changes in the central bank's relevant interest rates affect the aforementioned factors. The changes in the financial variables and expectations will thereafter result in changes in variables that will make sure that the change in the monetary policy transmits to the real economy. The variables that affects the real economy are, according to Mann (2023), the wage and price-setting behavior of households and businesses, along with decisions regarding consumption and investment. If there is a positive change in aggregate demand, it can put pressure on prices directly. Moreover, it can also be affecting prices and wages in the affected markets, and thereby affect domestic prices indirectly as well. Even though prices and wages are affected by the aggregate supply and demand in the economy, changes in prices and wages can affect the supply and demand of goods, as well as the labor market.

Furthermore, Mann (2023) points out that most of the lags that we see from monetary policy changes, are created in the transmission from the financial variables to the real economy variables. This is due to several things, but sticky prices, the rigidity of contracts, and the fact that agents' only have partial attentiveness are some of the reasons.

The efficacy of monetary policy depends on the functionality of these channels and their interactions, with expectations playing an essential role. Expectations influence both financial and real sectors with varying time lags and degrees of forward- versus backward-looking assessments concerning historical, current, and future data.

Moreover, Mann (2023) argues that there exists external factors beyond the central bank's control, such as changes in fiscal policy, global trade connections, commodity price fluctuations, and variations in risk preferences. There could be interactions between these factors, and the factors can either amplify or diminish the transmission of policy decisions. This is similar to the factors which European Central Bank (2023i) mentions, namely changes in; risk premia, bank capital, the global economy, fiscal policy, and commodity prices.

3 Literature Review

This thesis seeks to analyze the influence of monetary policy surprises on various financial variables. While significant research exists in the academic literature, ongoing discussions persist regarding the selection of an optimal identification strategy and the most effective approach for mitigating associated drawbacks. Over the course of identifying and evaluating the effects of monetary policy surprises on financial and economic variables throughout history, various identification strategies have been employed. The subsequent section provides a brief overview of the literature on high-frequency identification (HF) and the vector auto-regression approach (VAR), delineating their respective advantages and disadvantages.

3.1 High-Frequency Identification in Monetary Policy

Nakamura and Steinsson (2018b) state that one of the biggest challenge in macroeconomics lies in the identification of causal relationships. For instance, when it comes to monetary policy, central banks like the Federal Reserve and the ECB do not randomly select interest rates; their decisions are deliberate. This makes it difficult to pinpoint an aspect of monetary policy that is entirely independent of future economic conditions, which is essential for measuring the direct impact of policy on the economy.

Our research is particularly interested in a branch of macroeconomics that aims to identify variations in economic policies that can be reasonably assumed to be unrelated to other factors and then use these variations to evaluate policy effects. This approach is known as direct causal inference. However, there are significant challenges. The natural experiments we need to address our policy-related questions are seldom perfectly aligned with our needs. This leads to a problem of external validity, which can be broken down into four sub problems according to Nakamura and Steinsson (2018b):

1. Finding the effects of a policy change with one timing or impact profile does not necessarily provide insights into the effects of a policy change with a different timing or impact profile.

2. The consequences of fiscal policy changes depend on how monetary policy responds,

and similarly, the results of monetary policy are influenced by the response of fiscal policy.

3. The outcomes of both monetary and fiscal policies can vary depending on factors such as the economic slack (unused resources) and the openness of the economy (its interactions with the global economy).

4. Whether a policy action is a surprise or not can influence both the strength and the speed at which the economy reacts to the shock.

High-frequency identification emerges as an invaluable method for analyzing the impacts of monetary policy. This stems from the utilization of a narrow window around monetary policy news, which facilitates the isolation of such news from concurrent shocks occurring on the same day, week, month, or other relevant frequencies, depending on the chosen temporal resolution (Cesa-Bianchi et al., 2020). Gürkaynak et al. (2005) also emphasizes the employment of a narrow window around monetary policy announcements, as it enhances the precision in isolating the effects of monetary policy announcements on asset prices.

Moreover, Janson and Jia (2020) argues that the strength of high-frequency identification lies in the notion that fluctuations in asset prices within a narrow window around monetary policy announcements predominantly reflect aspects of the policy that were unanticipated by participants in the financial markets. As stated by Nakamura and Steinsson (2018a), the high-frequency identification approach exploits the fact that an excessive amount of monetary news is revealed during each monetary policy announcement. Given that the ECB conducts six monetary policy announcements per year (since 2015), a discontinuity-based identification approach, as exemplified by high-frequency identification around monetary policy announcements, can be employed (Nakamura & Steinsson, 2018a). Thus, through an analysis of changes in financial asset prices in a narrow window around monetary policy announcements, we can effectively identify surprises in monetary policy.

3.1.1 Window Size in High-Frequency Identification

Concerning the window size for high-frequency identification around monetary policy announcements, Gürkaynak and Wright (2013) advocates for minimizing it as much as possible. This recommendation is rooted in their findings that any jump in the conditional mean tends to conclude within 10 minutes of news announcements. Consequently, they posit that a window size of 20 minutes is optimal when examining the effects of news announcements in major markets. Nakamura and Steinsson (2018a), however, opts for a slightly broader window, spanning 30 minutes around announcements from the Federal Reserve.

Nevertheless, employing a high-frequency approach comes with certain limitations. According to Gürkaynak et al. (2005), using a narrow window will likely result in the model not being capable of capturing all the effects of monetary policy announcements. Their research indicates that financial market participants may require more time to assimilate and reach a consensus on the meaning of monetary policy statements by the FOMC, compared to the time needed to absorb information about changes in the federal funds target rate. Nonetheless, they underscore the importance of a narrow 30-minute window in their analysis, as it helps reduce noise in the dependent variable, thereby enhancing the precision of their estimates.

3.1.2 High-Frequency Identification and Endogeneity

When addressing endogeneity issues in monetary policy, high-frequency identification offers notable advantages. As highlighted by Bauer and Swanson (2023a), scrutinizing high-frequency interest rate changes around monetary policy committees' announcements, such as FOMC or the Governing Council, has become a crucial method for understanding the impact of monetary policy on asset prices and the macroeconomy. Some authors leverage monetary policy surprises to gauge effects on asset prices while others use them to estimate the effects of monetary policy on macroeconomic variables in a structural vector autoregression (SVAR). Monetary policy surprises are appealing in these applications because of their focus on variables that changes in a narrow window of time around monetary policy committees' announcements.

According to Bauer and Swanson (2023a), establishing causal effects from monetary policy announcements to financial variables requires certain assumptions. They argue that ruling out reverse causality is plausible by estimating effects within a narrow window around the announcement using intraday data. As the central bank decides on and formulates its decision well before the announcement, asserting that it reacts to asset price changes in this narrow window seems unreasonable. As highlighted by Altavilla et al. (2019), the key identifying assumption in their high-frequency approach is that monetary policy does not respond to asset prices within the day. This implies that monetary policy decisions cause reactions in asset prices, and not the other way around, within the short time window around the announcements, aligning with the argument presented by Bauer and Swanson (2023a).

According to Gürkaynak et al. (2005) monetary policy decisions are likely to be influenced by economic development in the time before the announcement, hence, also by changes in asset prices in the time before the monetary policy announcement. Moreover, they argue that due to the direct effect of stock market wealth on the economic outlook, any significant changes in the stock market could have an influence on the monetary policy decisions. Other macroeconomic news released earlier in the month or quarter might also be affecting both asset prices and the monetary policy decision. Therefore, using quarterly or monthly data will cause simultaneity as well as omitted variable bias. By using high-frequency data, they argue that these problems can be mitigated. Especially, the likelihood of other macroeconomic news affecting the monetary policy decision and/or the stock- or bond market within a short time period around any monetary policy announcement is smaller when employing the high-frequency approach. Hence, using high-frequency identification in monetary policy is likely to reduce the probability of and the effects of endogeneity in the model.

For the case of the US, Gürkaynak et al. (2005) argue that using daily data will cause problems regarding simultaneity in estimating the effects of monetary policy announcements. This is due to the fact that the FOMC at times changes the federal funds target rate just hours after the employment report have been released by the Bureau of Labor Statistics. Such situations are also something other central banks might face as well. To address this, Gürkaynak et al. (2005) propose the use of a sufficiently narrow time window, such as an hour or less, to ensure that monetary policy decisions are not influenced by external news or asset price changes, consequently enhancing precision in estimates.

Furthermore, Bauer and Swanson (2023a) raises concerns about omitted variable bias due to information preceding monetary policy, which may predict surprises and influence financial markets, potentially violating the assumption of no omitted variable correlating with surprises and affecting financial variables. However, they find that conditioning on the monetary policy surprise in the OLS regression eliminates the omitted variable bias in the estimate of the monetary policy surprise's impact on financial variables.

However, as discussed by Nakamura and Steinsson (2018a), the advantage of using high-frequency identification when it comes to ruling out the endogeneity problem in monetary policy come with certain costs. One significant drawback with the high-frequency identification is the substantial reduction in the statistical power of the estimated effects of monetary policy shocks.

3.1.3 High-Frequency Identification and Information Effects

The information effects that is inherent in central bank announcements also pose a challenge for external validity whenever researchers use responses to monetary policy shocks to draw conclusions about the effects of systematic monetary policy actions. Nakamura and Steinsson (2018a) points out that:

- Surprise monetary actions create information effects.
- Systematic responses by the monetary authority to new data do not.

This implies that unexpected monetary policy shocks could elicit larger responses than the systematic component of monetary policy.

Janson and Jia (2020) argues that the strength of high-frequency identification is that asset price fluctuations in a narrow window around monetary policy announcements will only be reflecting the aspects of the monetary policy that was not already expected by the participants in the financial markets, namely the surprise element. Thus, by analyzing the changes in financial asset prices in a narrow window around monetary policy announcements we will be able to identify monetary policy surprises, and thereby estimate the effects from monetary policy surprises on economic activity and inflation expectations. Moreover, they find that the information effect in monetary policy is well aligned with the direct effect of monetary policy (the change in the interest rate), as the information conveyed by central banks is about future output and not about inflation. Thus, the information effect affects the expectations for future output growth and not expected inflation. This is in line with what Nakamura and Steinsson (2018a) finds as well.

On the other hand, according to Bauer and Swanson (2023a), there is a substantial predictability of monetary policy surprises, which indicates that financial markets underestimate the Fed's responsiveness to economic conditions. Consequently, they propose the "Fed response to news", as outlined by Bauer and Swanson (2023b), as a credible alternative to the "Fed information effect." This perspective suggests that the Fed, and other central banks, do not have private information leading to an information effect, but rather emphasizes that market participants consistently underestimate the extent to which central banks reacts to economic conditions. Consequently, they argue that OLS regressions with high-frequency data, measuring the effects of monetary policy surprises on financial variables, yield reliable estimates.

Moreover, Andrade and Ferroni (2021) outlines that there are two types of information shocks that could result from a central bank's communication on future interest rates (forward guidance)—namely, Delphic and Odyssean shocks. The Delphic shock conveys information about the anticipated future macroeconomic state, to which the central bank will respond based on its standard policy rule. In contrast, the Odyssean shock imparts information about potential future deviations from the central bank policy rule, given a future macroeconomic state. Furthermore, Andrade and Ferroni (2021) argues that if these two shocks are present at the same time, they are likely to result in large reactions in the yield curve and very small reactions in stock prices. This opposite dynamic stems from the fact that while both shocks influence the yield curve in the same direction, they exert offsetting effects on stock prices. For example, a communication signaling lower future interest rates may simultaneously convey negative news about future macroeconomic outcomes (depressing stock prices) and the positive news of a more accommodative monetary policy (boosting stock prices).

3.2 Other Identification Methods

3.2.1 Vector Autoregression (VAR)

Nakamura and Steinsson (2018a) argues that it is especially difficult to identify monetary policy effects, particularly due to central bank actions often being responses to adverse shocks in the financial markets. If this is the case, then the effects from the monetary policy will be confounded with the financial shock, making it very hard to identify and distinguish the effects of the monetary policy from the shock to the financial markets. In economic research, the most common method for identifying external factors influencing monetary policy is to control for variables that are confounding. This approach is widely used in the VAR literature.

More than three decades ago, Sims (1980) provided a groundbreaking macroeconometric framework: vector autoregressions (VARs). Unlike a univariate autoregression, which is a single-equation, single-variable linear model based on the variable's own lagged values, a VAR extends this concept into an n-equation, n-variable linear model. In a VAR, each variable is explained not only by its own lagged values but also by the current and past values of the other $n-1$ variables. This framework methodically captures the complex dynamics in multiple time series, and the statistical toolkit accompanying VARs is both user-friendly and interpretable.

In the context of monetary policy, VAR models are instrumental in understanding how the economy responds to changes in policy. VAR models capture the dynamic relationship between multiple time series. In monetary policy, these time series could be interest rates, inflation, GDP growth, etc. By modeling these variables simultaneously, VAR helps in understanding the interdependencies and the impact of one variable on another over time. In VAR, identification can be achieved through techniques like imposing restrictions based on economic theory or using structural VAR (SVAR), where the restrictions are based on the economic structure (Stock & Watson, 2001).

More recent literature, such as in Nakamura and Steinsson (2018a, 2018b), argues that this approach comes with strong implicit assumptions and a strong potential for endogeneity even when controlling for confounding variables.

To demonstrate their point, Nakamura and Steinsson (2018b) consider the analysis performed by Cochrane and Piazzesi (2002). They discuss the unexpected drop in interest rates that occurred after the terrorist attacks on September 11, 2001, and argue that this event should be treated as an endogenous, not exogenous, monetary shock. After the attacks, the Fed made an unscheduled decision to lower the federal funds rate by 50 basis points on September 17. This drop was not anticipated by financial markets as of September 10. Markets were expecting some reduction in interest rates at the scheduled FOMC meeting on October 2. The Fed's decision to lower interest rates on the unscheduled meeting September 17 was a direct response to the attacks, and therefore an endogenous response as the Fed was forced to reassess its outlook for the economy. In a standard VAR, the model's controls would not capture the abrupt changes in beliefs and conditions caused by the 9/11 attacks. From the literature, we have identified two main drawbacks of using vector autoregression methods as opposed to high-frequency identification:

- **Implicit Assumptions:** VAR methods often rely on implicit assumptions, like the assumption that controlling for a few lags of specific variables suffices to encompass all endogenous influences on monetary policy. Additionally, VAR models often emphasize a crucial assumption related to timing. This assumption is designed to eliminate the possibility of reverse causality, meaning that variables like output and interest rates are not causing each other. To do this, researchers must decide whether the contemporaneous correlation between these variables represents one influencing the other, or if it is the other way around. Cloyne and Hürtgen (2016), claims that the VAR literature has mainly resolved the problem of simultaneity between interest rates and other macroeconomic variables by imposing a timing restriction. On the contrary, Nakamura and Steinsson (2018b) argues that making such assumptions does not magically solve the problem of simultaneity as it is very difficult to include all factors that affect policy at different times, and that these factors can be highly idiosyncratic.

- **Omitted Variable Bias:** VAR models may suffer from omitted variable bias. If relevant variables that affect policy decisions are not included in the analysis, variations in policy may erroneously be considered exogenous when they are, in fact, endogenous responses to the omitted variables. This can lead to incorrect assessments of the causes of economic changes.

High-frequency methods, on the other hand, offer precision by focusing on narrow windows around monetary policy news. By construction, they isolate specific events from other shocks occurring within the same time frame. In contrast, traditional VAR models might not capture the same level of precision because they work with larger timeframes.

Narrow windows in high-frequency methods reduce noise in the data, leading to more accurate estimates of the effects of monetary policy announcements. Nevertheless, it is still important to keep in mind that high-frequency methods come at the cost of reduced statistical power for estimating the effects of monetary policy shock.

3.3 Results From the Empirical Literature

Gürkaynak et al. (2005):

In the study by Gürkaynak et al. (2005), the authors aimed to investigate the effects of U.S. monetary policy on asset prices using a high-frequency event-study analysis. Contrary to the initial hypothesis that changes in the federal funds rate target alone could explain these effects, the research identified that two factors—the aforementioned "current federal funds rate target" factor and a "future path of policy" factor, could explain much of the variation in financial asset prices in a short window around monetary policy announcements. These factors were associated with both monetary policy actions and statements, with the latter having a more substantial impact on longer-term Treasury yields.

The second factor, linked to FOMC statements, accounted for a significant portion of the explainable variation in Treasury yields. The findings suggested that FOMC statements played a crucial role in shaping financial market expectations of future policy actions, highly influencing longer-term interest rates. More specific, they find that in two-year yields the statement explains about two-thirds of the variation, while in 10-year yields it explains about nine-tenths of the variation. Gürkaynak et al. (2005) argues that these findings can imply that when close to the ZLB, the FOMC may be able to credibly and effectively communicate its intentions to keep the federal funds target rate low for a longer period, and thereby stimulate economic growth.

Regarding the effect from surprises in the federal funds target rate, Gürkaynak et al. (2005) finds that a 1 percentage point surprise tightening on average is associated with about a 4,3% decrease in the S&P500 index, as well as increased yields in two-, five-, and 10-year Treasuries of 49, 28 and 13 bp, respectively. Furthermore, they find that a 1 percentage point innovation to the path factor, is associated with increased yields in five- and 10-year Treasuries of 37 and 28 bp, respectively. The path factor, however, have smaller effects on the stock market than what the federal funds target rate has, as shown by that a 1 percentage point innovation in the path factor only is associated with a decrease of 1% in S&P 500.

Nakamura and Steinsson (2018a):

In their article, Nakamura and Steinsson (2018a) employ a high-frequency identification approach based on movements in bond prices around scheduled FOMC meetings to isolate monetary shocks. For this, they focus on a 30-minute window surrounding these meetings. In their study, they find that nominal and real interest rates increase approximately one-for-one in response to interest hikes. Furthermore, they find that inflation reacts as expected, by being reduced after interest rate increases, however, this is only modestly and for longer horizons.

Moreover, the study documents an unexpected result—contractionary monetary shocks lead to an increase in survey estimates of expected output growth. This finding contradicts the conventional interpretation of monetary shocks, where tightening policy is expected to reduce output growth. To explain the unexpected increase in output growth expectations, Nakamura and Steinsson (2018a) propose a "Fed information effect." They argue that FOMC announcements not only affect beliefs about monetary policy but also influence private sector beliefs about other economic fundamentals. The Fed's communication about the strength of the economy may lead market participants to reassess their own economic outlook.

The study develops a model that incorporates both conventional monetary policy channels and the information effect. The model suggests that Fed announcements contain information about the path of the natural rate of interest, affecting private sector beliefs. Empirical estimates using the proposed model provide strong support for both the Fed information effect and conventional channels of monetary non-neutrality. Approximately two-thirds of the response of real interest rates to FOMC announcements is attributed to the response of the natural rate of interest, indicating the importance of information effects.

Altavilla et al. (2019):

Altavilla et al. (2019) examined the effects from monetary policy announcements in the euro area in the period 2002-2018, placing a special emphasis in the 2008 Financial Crisis. In their study they created and utilized the Euro Area Monetary Policy Event-Study

Database (EA-MPD) to analyze the impact of ECB communication on financial markets. They identified four key factors, "Policy Target", "Timing", "Forward Guidance", and "Quantitative Easing", as primary drivers of variations in the yield curve. Respectively, these factors are about the current policy rates, the future path of policy in the short- and medium term, and quantitative easing surprises.

Due to how the ECB announces their monetary policy, divided into a press release and a press conference, the study was able to reveal variations in the aforementioned factors across the different policy event windows. Notably, they found that Target surprises dominated in the press release window, and that this factor only affects the short end of the yield curve. Furthermore, the factors Timing, Forward Guidance and QE news influenced yield changes in the press conference window. The Timing factor encompasses the adjustment of policy expectations by altering the anticipated policy action between the current meeting and the subsequent one or the one thereafter, while maintaining longer-term policy expectations relatively unchanged. The Forward Guidance factor, according to Altavilla et al. (2019), influences the yield curve mostly in the medium term, while the QE factor influences the yield curve in the longer-term. Respectively, they find that the two factors have a peak effect on the yield curve after two- and 10 years. The Timing factor, which is also a sort of guidance factor, as the Forward Guidance factor, has a peak effect after about six months, thus affecting the nearer future than the Forward Guidance factor. For the euro exchange value, Altavilla et al. (2019) finds that monetary policy surprises have a significant effect on this, and that the uncovered interest parity (UIP)[4] dominates the "preserving the euro effect".[5] Thus, a surprise decrease in interest rates is associated with a depreciation of the euro.

Baumgärtner (2020):

In his research, Baumgärtner (2020) examined the effects from monetary policy announcements in the euro area. In his study, he utilized the EA-MPD.

The main findings in his research concern uncertainty. In this regard, Baumgärtner (2020) finds that the higher the uncertainty at the time of monetary policy publication, the more negative the stock price effect is. Thus, the uncertainty level can be determining the

[4]According to Chaboud and Wright (2005) the UIP relation postulates that the interest differential between two countries should equal the expected exchange rate change.

[5]"Preserving the euro effect" is when expansionary surprises results in an appreciation of the euro (Altavilla et al., 2019).

stock price effect to monetary policy announcements in the press release window. More precisely, his findings indicate that when the implied level of uncertainty in the economy, as represented by the VSTOXX index, exceeds 26.2 for Timing and 31.2 for Forward Guidance, restrictive monetary policy leads to a rise in stock prices. This is opposite of what one would usually expect. Furthermore, he finds that during periods of crisis, uncertainty is extraordinarily high. In a similar fashion, Baumgärtner (2020) also finds that information effects also occur more frequently during crisis.

In this section we have presented the current state of identification in macroeconomics, specifically identification in monetary policy. We have discussed the advantages and disadvantages of choosing between HF event studies or VAR monetary policy identifications. We have identified HF event studies as the preferred methodology for identification in current literature. In the following section we will be presenting the econometric framework employed in our estimation of monetary policy surprise effects in the euro area.

4 Empirical Methodology

In this section we will present the econometric framework and the data we have used to analyze the effects of ECB policy communication on a set of financial variables, commonly referred as *"monetary policy surprises"* in the literature. Our high-frequency identification methodology follows the one used by Altavilla et al. (2019).

We will start by presenting the econometric foundations for our high-frequency estimation in Section 4.1.1 – 4.1.3. Secondly, in Section 4.1.4 we will present the Euro Area Monetary Policy Event Study Database (EA-MPD), containing monetary policy surprises which Altavilla et al. (2019) have constructed and regularly update. Due to the restrictive access to intraday asset price data needed to build our own policy surprises, we will utilize this database. The last update of the EA-MPD was done on June 15, 2023, and we will adjust our analysis so that it extends to that date.

Lastly, in Section 4.2 we will present an identification strategy for *information shocks*, together with the data used, involving an examination of the predicted one-day variations surrounding policy announcements. The goal of this estimation is to study the presence of information shocks in the identified policy surprises in the recent turbulent period.

4.1 High-Frequency Identification

4.1.1 Monetary Policy Surprises

We have used the EA-MPD and framework by Altavilla et al. (2019) to calculate and measure the impact of monetary policy surprises on different financial market indicators. This methodology is based on Gürkaynak et al. (2005), Bauer and Swanson (2020), and Brand et al. (2010), and it involves a factor analysis coupled with imposed restrictions. We begin with the following model:

$$X^w = F^w \Lambda^w + \varepsilon^w$$

$$\text{with } w \text{ in } \{\textit{press release, press conference}\}$$

Where X^w denotes the observed changes in asset prices following ECB press releases. In our case, these are seven overnight indexed swap (OIS) rates across several maturities: one month, three months, six months, one year, two years, five years, and ten years. F^w is a matrix containing latent factors of dimension (NxT). Latent factors are unobserved variables that are hypothesized to underlie the observed variables. They are not directly measured but can be inferred from patterns in the observed variables.

Λ^w represents a matrix of the factor loadings, that describe how the changes in asset prices are influenced by the underlying latent factors associated with monetary policy events. Each element of this matrix represents how much a particular observed variable *"loads"* onto a specific latent factor. It indicates the strength and direction of the relationship.

ε^w represents the error term, which captures the idiosyncratic fluctuations.

When applying the matrix rank test developed by Cragg and Donald (1997) on the two distinct policy windows, we identify one statistically significant factor during the press release window. In the press conference period before the financial crisis of 2008, two factors are significant, and three factors are significant when considering the entire sample. Therefore, for $w = press\ release$, we use the first factor, and for $w = press\ conference$ we use the first three factors.[6]

4.1.2 Factor Rotation

The factors F^w cannot be directly interpreted as monetary policy surprises, as they are unique up to an orthonormal transformation. In other words, the precise economic interpretation of these mathematical constructs is dependent on how they are rotated or transformed. If they are not rotated, each factor will be correlated with all OIS futures, invalidating their interpretation.

An orthonormal transformation can be represented by a 3×3 matrix U. By applying transformation, we get new factors $\tilde{F^w} = F^w U$, and new loadings $\tilde{\Lambda^w} = U' \Lambda^w$.

$$X^w = \tilde{F^w}\tilde{\Lambda^w} + \tilde{\varepsilon^w}, \quad \text{where} \quad \tilde{F^w} = F^w U, \quad \text{and} \quad \tilde{\Lambda^w} = U' \Lambda^w.$$

The condition $UU' = I$ means that when the matrix U is multiplied by its transpose U',

[6] See Altavilla et al. (2019) for the detailed outcomes of the test.

the result is the identity matrix I. Any combination of U that satisfies this condition will satisfy the equation.

Economic restrictions are applied to identify a unique matrix U^*, such that the rotated factors $F^w = F^w U^*$ can be interpreted as orthogonal surprises, each of them describing a concrete dimension of monetary policy.

There are six restrictions given by orthonormality, on the elements of U. Three come from the columns of U having unit length:

$$U'_{.1}U_{.1} = 1, \quad U'_{.2}U_{.2} = 1, \quad \text{and} \quad U'_{.3}U_{.3} = 1,$$

and three from the columns of U being orthogonal:

$$U'_{.1}U_{.2} = 0, \quad U'_{.1}U_{.3} = 0, \quad \text{and} \quad U'_{.2}U_{.3} = 0,$$

Additionally, in order to identify the monetary policy factors, we impose three additional restrictions. According to the literature, it is important that the second and the third factors do not load on the one-month OIS, in order to keep ortonormality. This requirement gives the following two restrictions:

$$U'_{.2}\Lambda_{.1} = 0 \quad \text{and} \quad U'_{.3}\Lambda_{.1} = 0,$$

Finally, for the sake of interpretability of factors, it is important that the third rotated factor has minimum variance in the pre-crisis period (January 2, 2002 - August 7, 2008). This is the main idea behind the identification by Bauer and Swanson (2020), as this third factor will be the QE factor, which was a new instrument for monetary policy not introduced until the financial crisis in 2008. The thrid factor is $F^{w,pre}U_{.3}$ and its variance is $\sum_{t=1}^{T}\left(F_{t.}^{\text{pre}}U_{3.}\right)^2/T$

The rotation matrix u_{ij}, where j is the j-th column and i is the i-th row of the matrix, can thus be obtained solving the following optimization problem:

$$U^* = \arg\min_{\{u_{ij}\}} \frac{1}{T}\sum_{t=1}^{T}\left(F_{t.}^{\text{pre}}U_{3.}\right)^2$$

subject to

$$U'_{.2}\Lambda_{.1} = 0,$$
$$U'_{.3}\Lambda_{.1} = 0,$$
$$U'_{1}U_{.1} = 1, \quad U'_{.2}U_{.2} = 1, \quad U'_{.3}U_{.3} = 1,$$
$$U'_{1}U_{.2} = 0, \quad U'_{.1}U_{.3} = 0, \quad U'_{.2}U_{.3} = 0.$$

For completeness, and following the methodology in the literature, we have scaled the columns of $\tilde{F^w} = F^w U$ so that the resulting factors, which are Target Rate, Timing, Forward Guidance (FG), and Quantitative Easing (QE), are positively correlated with the one-month, six-month, two-year, and ten-year OIS rates, respectively. Therefore, positive factors can be interpreted as expressing restrictive monetary surprises.

4.1.3 Estimation Model

We depart from the basic regression model proposed by Bauer and Swanson (2020), which illustrates the relationship between monetary policy shocks and any given variable measured at high frequency:

$$\Delta x_t = \alpha + \beta_1 mp_t + \epsilon_t \tag{4.1}$$

where x is any high-frequency variable and mp_t are monetary policy shocks.

Adopting the approach of Altavilla et al. (2019), our identification strategy is that within a single day, monetary policy does not react to fluctuations in asset prices. Consequently, the causal relationship flows from monetary policy to asset prices, and not the other way around, enabling the study of financial markets' responses to monetary policy shifts. This identification, however, requires a measure for monetary policy surprises within a tightly defined timeframe around the ECB monetary policy announcements. To achieve this, high-frequency, tick-level data are employed to analyze the variations in financial variables coinciding with ECB press releases and conferences.

When estimating Equation 4.1, we need to consider that monetary policy surprises, following the ECB communication policy described in Section 2.4.3, affect different time windows. We analyze each time window in isolation to distinguish the differential effects.

Considering the following two time windows:

- $\Delta x_{\text{release}}$ describing the change of the high-frequency variables before and after the ECB press release
- $\Delta x_{\text{conference}}$ describing the change of the high-frequency variables before and after the ECB press conference.

The following are the main two regressions we aim to estimate.

$$\Delta x_{\text{release},t} = \alpha + \beta \text{Target}_t + \epsilon_t \tag{4.2}$$

$$\Delta x_{\text{conference},t} = \alpha + \beta \text{Timing}_t + \lambda \text{FG}_t + \theta \text{QE}_t + \epsilon_t \tag{4.3}$$

Where t is an index for ECB announcements, and Target_t, Timing_t, FG_t, QE_t represent the monetary policy surprises for a given announcement t.

Building upon the factors identified in the previous section, the target factor captures the dynamics of a given financial variable in response to the announcement of the ECB press releases. Conversely, the remaining surprises—namely, those associated with timing, forward guidance, and quantitative easing (QE)—result from the fluctuations in a given financial variable in the time window around the press conferences.

In Table 4.1 we present the financial assets whose intraday changes are computed around the announcement windows and that are included in the main database used for our analysis.

4.1.4 Dataset for the High-Frequency Identification

The dataset we employ encompasses monetary policy surprises categorized into press release, press conference, and a unified monetary event window which combines both release and conference windows. The EA-MPD series spans from January 7, 1999, to June 15, 2023. Our analysis, following Altavilla et al. (2019), focuses on data from January 2002 onward, bypassing the noisy OIS data preceding that period. The extension to mid-June 2023 allows us to explore the pandemic and its aftermath, a pivotal period for monetary policy.

Utilizing the EA-MPD database, where the monetary policy surprises in asset prices and yields are reported, we refrain from altering the monetary policy surprises. However, we provide an overview of Altavilla et al. (2019)'s construction methodology. The EA-MPD's data description is based on the appendix of Altavilla et al. (2019).

The high-frequency data, used in the construction of the EA-MPD, originates from the Thomson Reuters Tick History database, covering various assets, including the following according to Altavilla et al. (2019):[7]

Table 4.1: High-frequency dataset

Financial Variable	**Maturities**
Euro area OIS rates	1, 3, 6 months, 1–10, 15, 20 years
German bund yields	3, 6 months, 1–10, 15, 20, 30 years
French sovereign yields	2, 5, 10 years
Italian sovereign yields	2, 5, 10 years
Spanish sovereign yields	2, 5, 10 years
STOXX50E	
SX7E	
EUR/USD	
EUR/GBP	
EUR/JPY	

Note: The table shows the financial assets available in the EA-MPD.

In their estimation of surprises, the term structure of the OIS rates are used as a proxy for the risk-free rate curve in the euro area. In an ideal scenario, the risk-free rate curve should exclusively be proxied by the OIS rates mentioned above. However, detailed data on OIS rates for maturities beyond 2 years is only accessible after August 2011. Consequently, for the period preceding that date, Altavilla et al. (2019) resort to employing yields on German sovereign bonds as a substitute for the OIS rates, and use those as a proxy for the risk-free rate. Importantly, they find that the utilization of German yields consistently throughout the entire timeframe does not yield any notable discrepancies.

The high-frequency data used in constructing the EA-MPD underwent cleaning procedures. Altavilla et al. (2019) employed a meticulous process, involving the following:

[7] To see the full list of assets in the EA-MPD with Reuters Identification Code (RIC) see Table B.1 in the appendix of Altavilla et al. (2019).

1. Delete entries with a timestamp outside the interval when markets are open.
2. Delete entries with missing bid or ask price.
3. Delete entries with either the bid or the ask price larger in absolute value than 2500 basis points.
4. Delete entries for which the bid-ask spread is negative.
5. Delete entries with either the bid or ask price exactly equal to zero.
6. Delete entries for which the bid-ask spread is more than 50 times the median spread on that day.
7. Delete entries for which the mid-quote deviated by more than 10 mean absolute deviations from a rolling centered median of 50 observations (25 observations before and 25 after, excluding the observation under consideration).
8. When multiple quotes have the same timestamp, replace these with a single entry with the median bid and median ask price.

In their constructed database, Altavilla et al. (2019) computed changes in asset prices and yields during the press release, press conference, and monetary event windows. We will now outline how this was done.

For each window, they calculated the upper (post-press release, post-conference and post-event) and lower (pre-press release, pre-conference and pre-event) median quotes based on the last quote of each minute within the respective timeframes, employing the median of these quotes as the window's median. This meticulous methodology ensures a robust dataset for our analysis.

For the press release window, the change is computed as:

$$\text{Change}_t^R = \text{upper}_t^{med} - \text{lower}_t^{med} \tag{4.4}$$

Before July 21, 2022 the median quote was computed in the windows of 13:25-13:35 CET and 14:00-14:10 CET for the lower and upper window, respectively. After July 21, 2022 this changed to 13:55-14:05 and 14:30-14:40.

For the press conference window the change is computed in the same manner:

$$\text{Change}_t^C = \text{upper}_t^{med} - \text{lower}_t^{med} \tag{4.5}$$

Before July 21, 2022 the median quote was computed in the windows of 14:15-14:25 CET and 15:40-15:50 CET for the lower and upper window, respectively. After July 21, 2022 this changed to 14:30-14:40 and 15:55-16:05.

For the monetary event window, the same computational method applies, but the before and after windows where the median quotes are computed differ as shown below:

$$\text{Change}_t^M = \text{upper}_t^{med} - \text{lower}_t^{med} \tag{4.6}$$

Before July 21, 2022 the median quote was computed in the windows of 13:25-13:35 CET and 15:40-15:50 CET for the lower and upper window, respectively. After July 21, 2022 this changed to 13:55-14:05 and 15:55-16:05.

A final note regarding the composition of the EA-MPD database is the inclusion of US Initial Jobless Claims surprises. Altavilla et al. (2019) estimate the impact of US Initial Jobless Claims on OIS and German Bund yields, as the release of this is often coinciding with the press conference window of the ECB, and include it as a control in their main regressions. However, they discover that the potential confounding effects of the simultaneous release of initial jobless claims are minimal, meaning that any potential measurement error by omitting the variable is inconspicuous. They also assert that excluding the variable as an additional control in both the press release and press conference windows does not yield significant differences in the coefficients of interest in the OLS regressions. Consequently, given the scope of our thesis, we have opted not to incorporate them as a control in our analysis.

4.2 Information Shocks Identification

Recent literature emphasizes the influence of two factors identified from high-frequency monetary surprises in shaping financial market responses to central bank communications.

These factors include news regarding future conventional monetary policy shocks, referred to as Odyssean shocks, and the revelation of information about future macroeconomic conditions, known as Delphic or Information shocks. According to Andrade and Ferroni (2021), these two shocks cause the yield curve to move in the same direction but exert opposite effects on financial conditions and macroeconomic expectations. Additionally, Andrade and Ferroni (2021) contends that the distinct effects of the two shocks on macroeconomic outcomes imply that central bankers are unable to deduce the extent of the stimulus they offer simply by observing the yield curve's response.

The methodology developed by Andrade and Ferroni (2021) allows to identify each of the two shocks from a single monetary policy surprise. Understanding how market policy signals are interpreted and internalized by financial markets is important in evaluating the effectiveness of monetary policy.

The simultaneous presence of Delphic and Odyssean shocks in central bank messages provides clarity on why forecasts about future interest rates elicit significant reactions in the yield curve, but only weak reactions in inflation expectations and stock values. Essentially, while both shocks push the yield curve uniformly, they exert contrasting influences on these financial indicators. Consider expected inflation as an example: a message indicating reduced future interest rates might simultaneously convey negative prospects for future economic conditions, leading to diminished anticipated inflationary pressures—and positive news about a more relaxed monetary policy stance, as the central bank indicates a future departure from its standard policy response, which in turn, could heighten inflation expectations.

Building on the research by Karadi (2017) and Andrade and Ferroni (2021), our identification strategy involves assessing the prevalence of information shocks in the sample. Nominal rates, stock prices, and inflation-linked swaps moving in the same direction is indicative of information shocks.

To address the issue of intraday data on inflation-linked swaps not being consistently accessible, we modify our approach to a daily frequency. We assess the reaction of interest rates by calculating the fitted value of the one-day shift (surrounding the policy events) in the 2-year Overnight Index Swap (OIS), regressed against the intraday factors. Similarly, we apply this method to evaluate the one-day changes in inflation-linked swaps and the one-day log-difference in stock prices.

4.2.1 Estimation Model

Considering the following two time windows:

- $\Delta y_{\text{release}}$ describing the change of the given variables at a daily frequency, before and after the ECB press release.
- $\Delta y_{\text{conference}}$ describing the change of the given variables at a daily frequency, before and after the ECB press conference.

We assess how markets react to the information that is released via ECB communications on the days of press release and conference by running the following regressions:

$$\Delta y_{\text{release},t} = \alpha + \beta \text{Target}_t + \epsilon_t \tag{4.7}$$

$$\Delta y_{\text{conference},t} = \alpha + \beta \text{Timing}_t + \lambda \text{FG}_t + \theta \text{QE}_t + \epsilon_t \tag{4.8}$$

Where t is an index for ECB announcements, Target_t, Timing_t, FG_t, QE_t represent the monetary policy surprises for a given announcement t.

4.2.2 Dataset for the Information Shock Identification

We have constructed a dataset containing financial variables at the daily frequency in order to study the prevalence of information shocks in the period studied. Table 4.2 illustrates the contents of this dataset. The dataset we employ encompasses spans from January 3, 2002 to June 15, 2023. The reason for the mismatch between the beginning of the daily dataset and the beginning of the EA-MPD database, is the low availability of daily data for Inflation Linked Swaps (ILS) prior to 2002.

Table 4.2: Daily dataset

Financial Variable	**Maturities**
Euro area OIS rates	2Y, 5Y, 10Y
Inflation Linked Swaps (ILS)	2Y
Log of STOXX50E	

Note: The table shows the financial assets comprising the daily frequency dataset. Data until 09/2018 retrieved from Altavilla et al. (2019) appendix, data from 09/2018 onwards retrieved from Thomson Reuters and Bloomberg databases.

The dataset is later merged with the identified factors constructed using intraday data; Target, Timing, FG, and QE respectively, according to the methodology described in Section 4.1.2

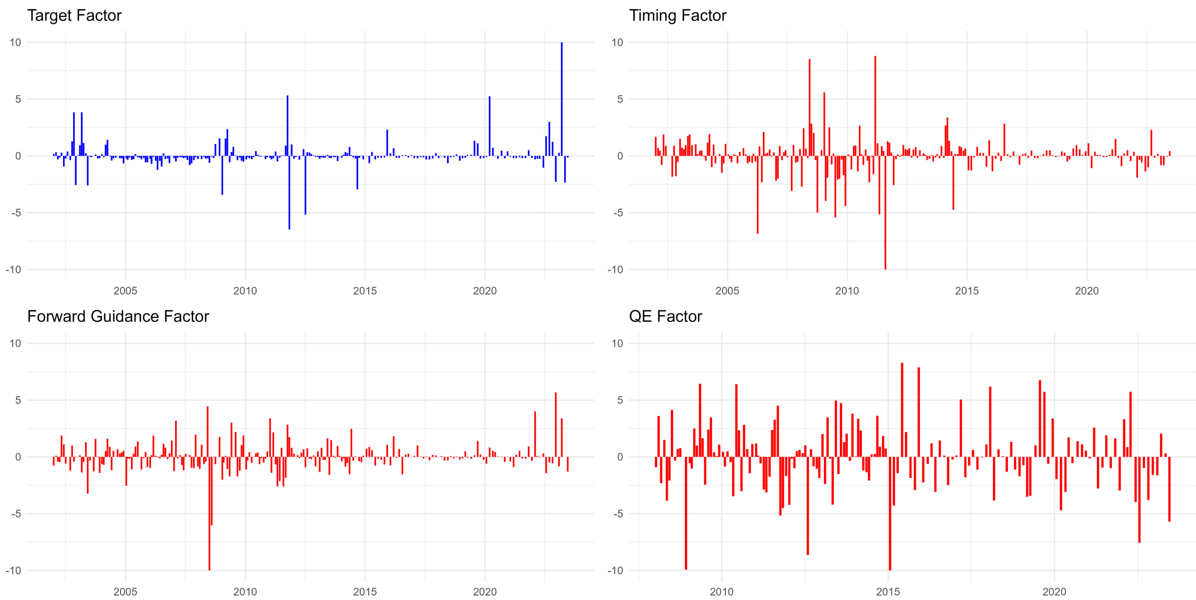
5 Results and Discussion

In this section, we present the empirical findings from our high-frequency identification, where we regress monetary policy surprises, as identified by the factors Target, Timing, Forward Guidance, and Quantitative Easing, on a set of important financial variables. More specifically, we will delve into the intricacies of the ECB's response to the unprecedented challenges posed by the pandemic. We complement our analysis by comparing the recent policy surprises with those of previous years and evaluate if the responsiveness of financial markets to policy shocks has been larger during and in the aftermath of the Covid-19 pandemic. Finally, we will examine the different interpretation of policy surprises by market participants by analyzing the presence of information effects in our data.

5.1 Market Surprises and Factor Contributions

In the following section, we examine the factors Target, Timing, Path (Forward Guidance), and QE as outlined in Section 4.1.2. We first focus on their progression over time during both the press release and conference windows, presented as time series in Figure 5.1.

Figure 5.1: Estimated factors in the press release window (blue) and the press conference window (red), 2002-2023



Note: The figure presents an estimation of the identified factors across time, expressed in basis points. The factors are scaled so that the Target has a unit effect on the one-month Overnight Indexed Swap (OIS), Timing impacts the six-month OIS to the same extent, Forward Guidance affects the two-year OIS, and Quantitative Easing (QE) exerts a the same unit effect on the ten-year yields.

Target Factor

The largest realizations for the Target factor, as it can be seen in the top left panel, take place during 2011 and 2023 respectively. As identified in Altavilla et al. (2019), on November 3, 2011, the ECB cut its policy rates by 25 basis points. This was an unexpected surprise to markets, specially as the cut coincided with the first meeting of Mario Draghi as the president of the ECB. In 2011, Europe was still grappling with the aftermath of the 2008 financial crisis and facing a sovereign debt crisis. By reducing interest rates, the ECB aimed to stimulate the economy, encourage lending, and boost investment and consumption. The unexpected nature of this decision may have been intended to have a stronger impact, showing the ECB's readiness to take decisive action. Draghi's decision marked a departure from the policies of his predecessor, Jean-Claude Trichet. Under Trichet, the ECB had actually raised interest rates earlier in 2011, a decision that was increasingly viewed as unsuitable given the escalating debt crisis. The rate cut under Draghi indicated a more accommodative monetary policy approach (Kollewe, 2011). By acting decisively at his first meeting, Draghi influenced market expectations about future ECB policies. It set a tone for his tenure, suggesting he would be proactive and responsive to economic conditions.

Following the reduction of the deposit facility rate to zero on July 5, 2012, which is evident from a significant negative value for the Target surprise, subsequent fluctuations in the Target factor have been relatively minor until 2020. With notable exceptions in 2014 and 2015, coinciding with unexpected further reduction into negative territory of the deposit facility rate.

The interval from 2020-2023 saw momentous monetary policy surprises. Firstly, in March 2020, as the Governing Council of the ECB unveiled an extensive array of measures in response to the Covid-19 pandemic. This included the launch of the €750 billion Pandemic Emergency Purchase Programme (PEPP) on March 18, 2020. In a striking display of responsiveness, this program was expanded by €600 million within a month, and by another €500 billion by December.

Subsequent notable policy surprises were observed in 2022, particularly on July 21, when the ECB raised its key interest rates by 50 basis points, marking the first rate hike since the rate hike by Trichet in 2011, aimed at mitigating soaring inflation. The most substantial surprise within the entire period under review occurred on March 16, 2023, with a 50 basis point surge in the policy rates, elevating the interest rate on MRO's to 3.50%, which stands as one of the highest levels since the euro's inception. This substantial rate hike likely influenced inflation expectations, with market participants potentially changing their beliefs about the ECB's willpower in curbing inflation after several 50- and 75 basis point increases. This interpretation aligns with the observed positive sign and magnitude of the surprise. The noteworthy rate increase, coupled with the ECB's statement in its press release where they state that inflation is projected to remain too high for too long, might have instilled expectations among market participants of additional large interest rate hikes in the future. This strong statement coupled with the high interest hike could therefore explain the surprise evident in Figure 5.1.

Timing Factor

The volatility of the Timing factor in the conference window for the period after 2012 has declined significantly, with the last large surprise taking place when the deposit facility was brought down to zero in July 2012. The period from 2008 to 2011 saw the largest Timing factor realizations, aligned with pivotal press conference disclosures. In the latest period under review, the ECB reached its highest point of interest rate increases on September 8, 2022, with a significant rise of 75 basis points. This marked the second hike following the initial increase on July 21, 2022. This development likely led to a shift in market expectations about future interest rate trends, as investors and financial markets braced for further adjustments in the ECB's interest rate policy. More active monetary policy, since the aftermath of the Global Financial Crisis, and especially during the 2020-2023 period, has potentially contributed to less timing of policy surprises. As markets adapted to the heightened level of uncertainty during this period, they may have also become more resilient to policy changes, viewing them as a normal part of the economic landscape rather than as unexpected events.

Forward Guidance Factor

In line with results presented by Altavilla et al. (2019), the most significant event in the Forward Guidance factor during the conference window happened on July 3, 2008, as an unexpected negative shift. Intriguingly, on this date, there was a policy rate hike of 25 basis points, an event that was anticipated and reflected by the minimal change in our Target factor. However, the press conference conveyed a halt in future rate increases, prompting the markets to adjust their expectations and discard the likelihood of subsequent hikes. Post-financial crisis, notable realizations were recorded in December 2022 and March 2023, each coinciding with unanticipated 50 basis point rises in the key interest rates. These surprises coincide respectively with the announcement of a €15 billion decline per month in reinvestment of principal payments from maturing securities until the end Q2 2023, and the goal of discontinuing the reinvestments under the Asset Purchase Programme (APP) as of July 2023.

Quantitative Easing Factor

For the QE factor, the conference window's most pronounced realization occurred on January 22, 2015, during the announcement of the ECB's APP. Before the announcement, there had been considerable uncertainty about how and when the ECB would implement QE, especially given the complexity of the Eurozone, which comprises multiple countries with diverse economic conditions. This kind of large-scale asset purchasing was a significant step for the ECB and signaled a more aggressive stance in addressing economic challenges in the Eurozone, contributing to the market's reaction.

In the 2020-2023 window, the QE factor's largest absolute realization emerged as a negative surprise on July 21, 2022, when the ECB announced an interest rate hike—the first since 2013—potentially. In June of the same year, the announcement of the termination of net purchases under the APP from July 1, 2022, signaled to the markets an impending reduction in expansionary measures related to the QE program. Moreover, more significant surprises were realized during the subsequent interest rate hikes in March 2023 coinciding with the announcement of ending reinvestments under the APP starting from July 2023.

Notably, the QE factor surprises have exhibited a persistent volatility ever since this policy instrument's introduction. QE is an unconventional monetary policy tool used typically in extraordinary economic circumstances, such as during severe recessions or periods of deflation. Because it's used in such critical and often unpredictable times, the market's reaction to QE announcements and implementations can be highly volatile. Additionally, there is often uncertainty about the impact and effectiveness of QE policies. This uncertainty can lead to volatility as markets try to price in the potential effects of QE on inflation, interest rates, economic growth, and asset prices.

5.1.1 Factor Loadings

Figure 5.2 shows the loadings of the rotated factors over the seven maturities in the analysis. Our methodology is underpinned by the orthogonality conditions we have previously outlined in Section 4.1.2. Employing a matrix rank test, similar to the one proposed by Cragg and Donald (1997), we identify a singular factor during the press release window and three distinct factors throughout the press conference window. It is worth noting that the third factor predominantly emerges in periods characterized by Quantitative Easing (QE), yet the rotated factor loadings remain constant across the entire time span.

The factors are rotated to align with our orthogonality assumptions, enhancing their interpretability. The resulting factor loadings, as depicted in Figure 5.2, offer additional insights into how these factors influence the yield curve. The figure highlights that the Target factor predominantly influences the shorter end of the yield curve. The Timing factor is also notably impactful on relatively short-term yields, peaking between the 1-month and 2-year yields. As anticipated, the Forward Guidance factor predominantly affects the medium-term segment of the yield curve. Analyzing the impact of QE reveals that its influence intensifies with the extension of bond maturities. This observation is in harmony with the ECB's strategic use of various maturities in its QE program, which, as Altavilla et al. (2019) note, averaged around eight years. Consequently, the pronounced effect of QE on the longer end of the yield curve is a logical outcome, mirroring trends observed in similar initiatives within the United States.

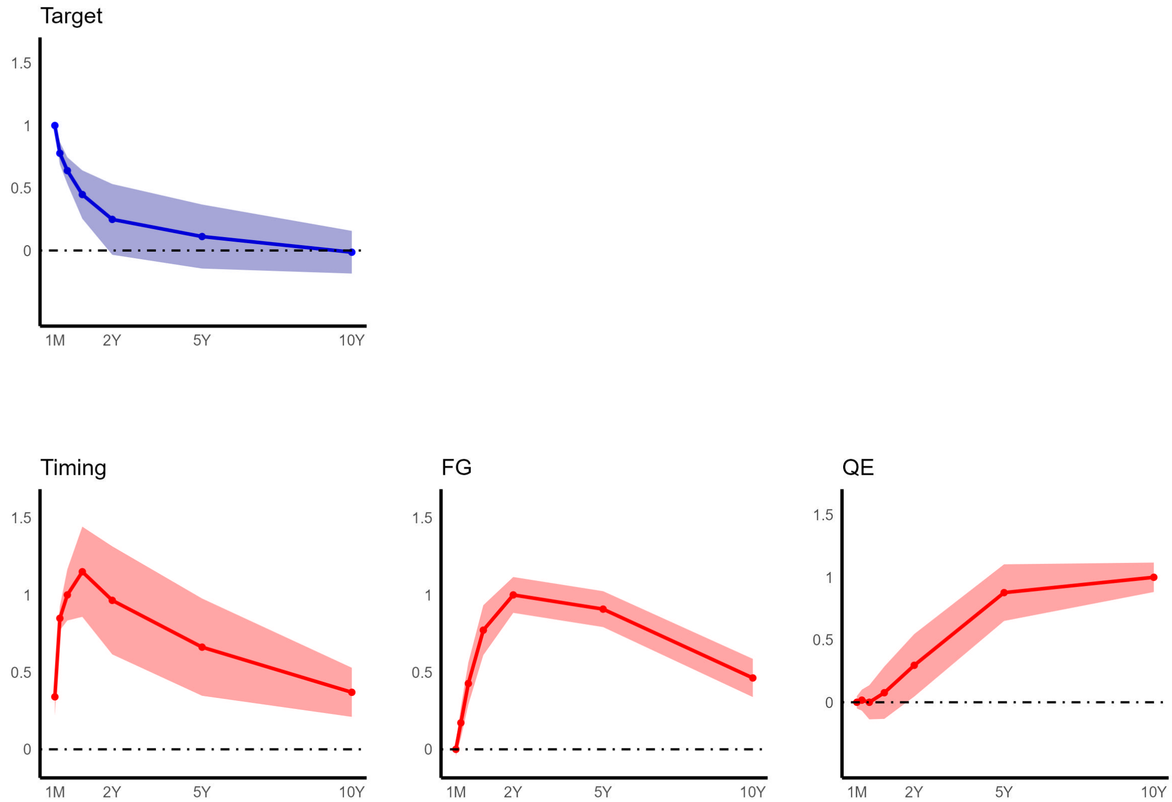
5.1.2 Relative Contribution of Factors

When comparing the relative contribution of the four factors with the findings of Altavilla et al. (2019), our estimation outcomes in Table 5.1 closely align with their findings regarding the factors influencing the variance in the OIS rates in the euro area.[8]

The Target factor demonstrates heightened explanatory power in our analysis, surpassing Altavilla et al. (2019)'s findings by explaining 99.1% of the variance in 1-month OIS rates, compared to their 97.8%. In Figure 5.2 it is evident that the Target factor loads mostly on the OIS rates with the shortest maturities, diminishing as the maturity increases. In

[8]For another description of the findings of Altavilla et al. (2019), see section 3.3.

Figure 5.2: Factor loadings



Note: The figure presents the factor loadings, measured in basis points, for both the press release (upper panel) and press conference (lower panel) periods. For each specific maturity span within these timeframes, the loadings have been calculated by regressing the identified surprises against the relevant factors. We have normalized the Target and Timing factors to achieve a one-unit impact on the 1-month and 6-month OIS rates, respectively. In a similar way, the Forward Guidance and QE factors have been scaled to have a unit effect on the yields of 2-year and 10-year bonds, correspondingly. The areas highlighted in the figure illustrate the 90 % confidence intervals.

the conference window, the Target factor is notably absent, exerting no influence on any of the OIS rates. More sudden and significant hikes in interest rates in the 2020-2023 are potentially behind the increase explanatory power of the Target factor in our analysis.

The Timing factor, while still exercising influence, explains slightly less of the variance across the various OIS maturities during the conference window in our findings compared to Altavilla et al. (2019). Their results for the Timing factor explain 86.7% and 70.3% of the variance in 3 and 6-month OIS rates respectively, whereas we report 84.6% and 63.1% for the same rates. However, in line with the results of Altavilla et al. (2019), it emerges as the most influential factor for explaining the variance in the 3- and 6-month OIS rates. As depicted in Figure 5.2, the Timing factor loads most on the relatively short maturities

Table 5.1: Relative contribution of factors in explaining policy surprises, full sample

	1-month	3-month	6-month	1-year	2-year	5-year	10-year	SD Factor
Press release:								
Target	99.1	79.2	67.5	30.6	8.4	1.9	0.1	2.7
Residual	0.9	20.8	32.5	69.4	91.6	98.1	99.9	NA
SD OIS rel.	2.7	2.4	2.1	2.2	2.3	2.2	1.7	NA
Conference:								
Timing	52.5	84.6	63.1	41.6	22.7	11.4	7.2	2.1
Forward Guidance	0.0	10.5	35.0	57.1	74.3	65.4	34.6	3.7
QE	0.0	0.0	0.0	0.2	2.2	20.8	55.3	2.1
Residual	47.5	4.9	1.9	1.1	0.8	2.3	2.8	NA
SD OIS conf.	1.0	1.9	2.6	3.7	4.2	4.1	2.9	NA

Note: The table reports, for the maturity of the OIS rates indicated in the first row, the fraction of the variance (in percentage points) explained by Target factor in the press release window and by each of the three factors (Timing, Forward Guidance, and QE) in the conference window. The row labeled "Residual" reports the variance not explained by the factors. The last row in each panel shows the variance of the OIS rate at the relevant maturity measured in the release and conference windows respectively. The last column reports the standard deviations of the four factors.

(short medium-term), however, with less impact on the shortest maturity, represented by the 1-month OIS rate.

Contrastingly, the Forward Guidance (FG) factor demonstrates increased explanatory power in our results, compared to the ones in Altavilla et al. (2019). Whereas they report that the FG factor represents 68.9% of the variance in 2-year OIS rates, we find that for our sample 74.3% of that variance is explained by the FG factor. The FG factor has no impact on the 1-month OIS rate, but for OIS rates with maturities of three months or more, it exerts influence. Consistent with the findings in Altavilla et al. (2019), the FG factor is best at explaining the variance in the 1-, 2-, and 5-year OIS rates, with the highest explanatory power on the 2-year OIS rate. This is evident in Figure 5.2 also, as the FG factor loads most on the 2- and 5-year OIS rates.

Post-2018, in response to economic challenges such as the Covid-19 pandemic, central banks have relied more heavily on forward guidance to influence longer-term interest rates and economic expectations. This shift could mean that the timing of policy changes has become less influential as markets now place more weight on the central banks' communicated intentions and future policy paths, thus explaining the difference in our findings with those of Altavilla et al. (2019) regarding the Timing and Forward Guidance factors.

Regarding the QE factor, its impact on OIS rates with maturities less than five years is minimal. Our estimates indicate a greater capacity of the QE factor in explaining the variance in 10-year OIS rates compared to Altavilla et al. (2019). Specifically, we find that the QE factor explains 55.3% of the variance in the 10-year OIS rate, while the results in Altavilla et al. (2019) suggest that the QE factor explains 50% of the variance. This result aligns with Figure 5.2, illustrating that the QE factor predominantly influences the longest maturities.

Furthermore, during the conference window, our standard deviation is generally smaller or the same for all OIS rates, except for the 10-year OIS rate, where it is only marginally higher than reported by Altavilla et al. (2019).

5.2 High-Frequency Identification Regressions

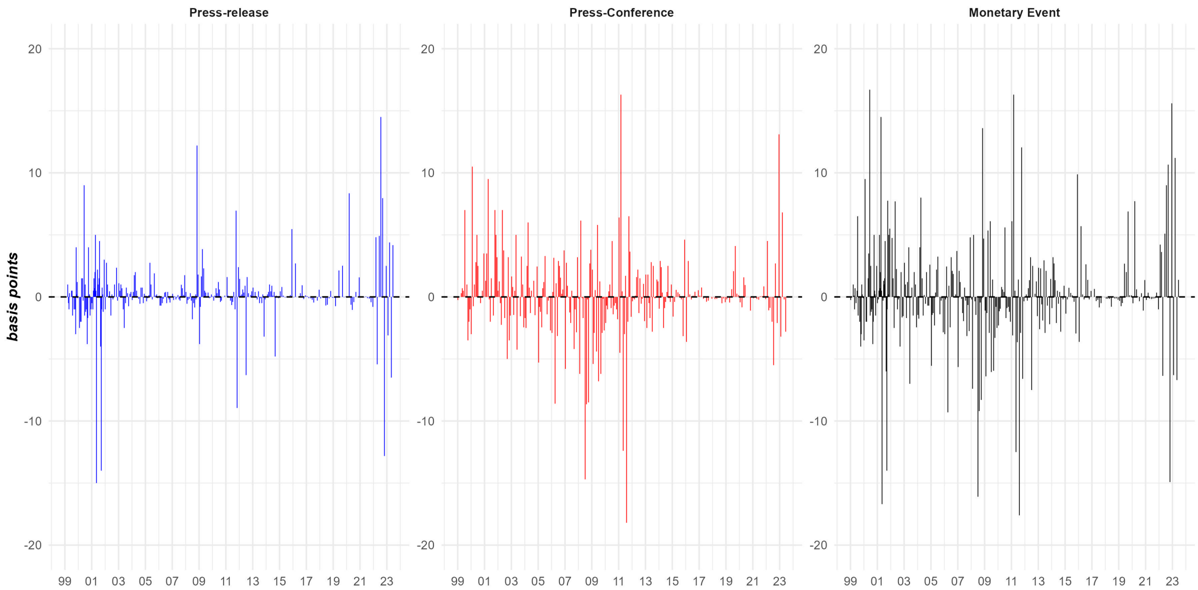
A compelling question is whether these factors exhibited consistent behavior across the entire sample period (2002-2023) or if policy surprises triggered different responses in the studied financial variables in the period prior to and following the Covid-19 pandemic. Employing Ordinary Least Squares (OLS) regression analyses, using the EA-MPD database, we scrutinize the influence of unexpected policy decisions on critical financial indicators. These indicators include Overnight Index Swap (OIS) rates, the Euro-dollar exchange rate, a spectrum of government bond yields, and stock market indices, including the broad Euro Area STOXX50E and the sector-specific Euro Area Bank Stock Market Sub-Index (SX7E).

Our analysis is particularly concentrated on two distinct periods: the years 2014-2020, which capture the landscape leading up to the Covid-19 pandemic, and the subsequent period from 2020 to 2023.

5.2.1 OIS Rates Response to Policy

Figure 5.3 illustrates the volatility of the euro area one-year overnight index swap (OIS) yield changes from 1999 to 2023, segmented into the three key windows: press releases, press conferences, and monetary events. Notable fluctuations can be observed during periods of significant economic stress. For instance, there is a marked increase in yield changes around the 2008 financial crisis, reflecting the market's reaction to emergency fiscal policies and bank bailouts. Similarly, the graph shows significant movement during the Covid-19 pandemic onset in 2020, where yields likely responded to unprecedented global lockdowns and economic uncertainty. More recently, the graph indicates a heightened frequency and amplitude of changes, potentially corresponding to the periods of high inflation and subsequent interest rate adjustments by central banks in response to post-pandemic economic conditions. These visual data points underscore the sensitivity of OIS yields to major economic events and the overarching impact of fiscal and monetary policy announcements on market expectations.

Figure 5.3: One-year OIS yield changes 1999-2023.



Note: The graph shows changes in OIS yields for the sample period covered by the EA-MPD dataset around the press release, press conference and monetary event windows. Data used for constructing the graph is retrieved from the EA-MPD dataset.

Analyzing Table 5.3 and Table 5.4 we identify how the Target factor's influence on one-month OIS rates remains pronounced across subsamples and exhibits minimal variation, suggesting stability in its impact. Surprisingly, we identify a marginal decline during 2020-2023 of the effect of the Target factor.

This subtle reduction in the Target factor's effect could be ascribed to market participants increasingly anticipating interest rate changes in this subsample, possibly due to the continued presence of the ECB's forward guidance and the increasing inflation levels. Despite this, the Target factor maintains a significant impact on short-term rates, with its effect diminishing as the maturity of the security increases, affirming its role in shaping immediate interest rate expectations.

In contrast, the Timing factor displays more variation across subsamples. In the full sample, in Table 5.2, it has the most substantial effects on the 6-month and 1-year OIS rates. In the 2014-2020 subsample, in Table 5.3, it dominates the 1-year and 2-year OIS rates, while in the 2020-2023 subsample, it once again exerts the most substantial effects on the 6-month and 1-year OIS rates. It is notable how much larger the effect from the Timing factor is in the 2020-2023 subsample compared to the 2014-2020 subsample. This notable increase in its effect may be due to market reactions becoming more sensitive to when the ECB made policy announcements, especially given the uncertain economic climate brought on by the Covid-19 pandemic and its aftermath. It seems that the intense attention on the ECB's policy decisions during these challenging times has elevated the importance of the Timing factor, with investors closely analyzing how each action by the ECB could influence economic recovery. However, its impact is predominantly on the short medium-term, with lesser effects on the OIS rates with the shortest and longest maturities.

The Forward Guidance factor consistently affects medium-term rates across the observed periods, suggesting that the ECB's communicated outlook has a persistent and stabilizing effect on market expectations for future interest rates, as reflected in the one-year, two-year, and five-year OIS rates.

Lastly, the QE factor's influence is most potent on the ten-year OIS rates, which resonates with the intended long-term orientation of quantitative easing measures. As Altavilla et al. (2019) suggest, the QE program's average maturity aligns closely with this decade-long horizon, reinforcing the factor's enduring impact on long-term rates.

Table 5.2: Estimated effects of monetary policy surprises on OIS yields, 01/2002-06/2023

VARIABLES	(1) OIS 1M	(2) OIS 3M	(3) OIS 6M	(4) OIS 1Y	(5) OIS 2Y	(6) OIS 5Y	(7) OIS 10Y
Panel A: Press release window							
Target	1.00***	0.78***	0.64***	0.45***	0.25*	0.11	-0.01
	(0.01)	(0.05)	(0.06)	(0.10)	(0.14)	(0.12)	(0.08)
Observations	223	223	223	223	223	223	223
R-squared	0.99	0.79	0.68	0.31	0.08	0.02	0.00
Panel B: Conference window							
Timing	0.34***	0.85***	1.00***	1.17***	0.96***	0.66***	0.37***
	(0.07)	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
FG	-0.00	0.17***	0.43***	0.77***	1.00***	0.91***	0.46***
	(0.03)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
QE	-0.00	0.02	-0.00	0.08***	0.30***	0.88***	1.00***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)	(0.03)
Observations	218	218	218	218	218	218	218
R-squared	0.53	0.95	0.98	0.99	0.99	0.98	0.97

Note: The table shows the reaction of OIS and German sovereign yields at different maturities to surprises in monetary policy. Coefficients are expressed in percentage per annum per standard deviation change in the factors. Robust standard errors in parentheses; ***,**,and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 5.3: Estimated effects of monetary policy surprises on OIS yields, 01/2014-01/2020

VARIABLES	(1) OIS 1M	(2) OIS 3M	(3) OIS 6M	(4) OIS 1Y	(5) OIS 2Y	(6) OIS 5Y	(7) OIS 10Y
Panel A: Press release window							
Target	1.01***	0.84***	0.88***	0.77***	0.79***	0.64***	0.29
	(0.03)	(0.07)	(0.09)	(0.12)	(0.16)	(0.21)	(0.25)
Observations	53	53	53	53	53	53	53
R-squared	0.98	0.84	0.84	0.72	0.60	0.33	0.07
Panel B: Conference window							
Timing	0.60***	0.91***	0.91***	1.01***	1.03***	0.81***	0.23***
	(0.13)	(0.08)	(0.04)	(0.04)	(0.04)	(0.09)	(0.07)
FG	-0.05	0.14***	0.50***	0.75***	1.00***	0.89***	0.48***
	(0.07)	(0.05)	(0.02)	(0.03)	(0.02)	(0.05)	(0.04)
QE	-0.07**	-0.04	0.03*	0.15***	0.29***	0.78***	1.09***
	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	(0.06)	(0.04)
Observations	42	42	42	42	42	42	42
R-squared	0.71	0.88	0.96	0.96	0.99	0.97	0.99

Note: The table shows the reaction of OIS and German sovereign yields at different maturities to surprises in monetary policy. Coefficients are expressed in percentage per annum per standard deviation change in the factors. Robust standard errors in parentheses; ***,**,and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 5.4: Estimated effects of monetary policy surprises on OIS yields: 02/2020-06/2023

VARIABLES	(1) **OIS 1M**	(2) **OIS 3M**	(3) **OIS 6M**	(4) **OIS 1Y**	(5) **OIS 2Y**	(6) **OIS 5Y**	(7) **OIS 10Y**
Panel A: Press release window							
Target	0.99***	0.83***	0.65***	0.36**	0.05	-0.11	-0.16
	(0.01)	(0.12)	(0.12)	(0.17)	(0.21)	(0.17)	(0.11)
Observations	27	27	27	27	27	27	27
R-squared	0.99	0.70	0.53	0.13	0.00	0.01	0.06
Panel B: Conference window							
Timing	0.05	0.60***	1.17***	1.53***	0.67***	0.55***	0.53***
	(0.12)	(0.08)	(0.10)	(0.09)	(0.09)	(0.05)	(0.05)
FG	-0.07*	0.08***	0.48***	0.87***	0.95***	0.82***	0.55***
	(0.04)	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)
QE	0.07	0.05*	-0.05	0.04	0.36***	0.86***	1.00***
	(0.04)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.02)
Observations	27	27	27	27	27	27	27
R-squared	0.28	0.76	0.96	0.99	0.99	0.99	0.99

Note: The table shows the reaction of OIS and German sovereign yields at different maturities to surprises in monetary policy. Coefficients are expressed in percentage per annum per standard deviation change in the factors. Robust standard errors in parentheses; ***,**,and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

5.2.2 Exchange Rate Responses

When examining the effect on the exchange rate in Table 5.5, we find no statistically significant effect from the monetary policy surprises on the euro exchange value in the press release window. In the press release window, the R-squared is also very small, meaning that the target factor does not explain much of the variance in the EUR/USD exchange rate.

However, when looking at the conference window, we find that the monetary policy surprises of Forward Guidance exert statistically significant effects on the exchange rate in all sample periods. The Timing and QE factors also exerts significant effects on the exchange rate, however, not in the 2020-2023 subsample. Our analysis, consistent with the results of Altavilla et al. (2019), reveals that an increase in interest rates beyond expectations in the euro area results in an appreciation of the euro. Based on our findings, it is evident that alterations in interest rate expectations across mostly medium-term maturities, driven by monetary policy communication, have a significant impact on the exchange value of the euro in the 2020-2023 subsample. In the other subsamples, interest rate expectations both for shorter- and longer-term maturities also have significant effects on the exchange rate value of the euro.

Table 5.5: Estimated effects of monetary policy surprises on the exchange rate

Panel (A): Press release window

VARIABLES	(2002-2023) EUR	(2014-2020) EUR	(2020-2023) EUR
Target	0.01	0.10	-0.00
	(0.01)	(0.06)	(0.01)
Observations	223	53	27
R-squared	0.03	0.18	0.00

Panel (B): Conference window

VARIABLES	(2002-2023) EUR	(2014-2020) EUR	(2020-2023) EUR
Timing	0.06***	0.18***	0.04
	(0.01)	(0.06)	(0.09)
FG	0.04***	0.18***	0.05**
	(0.01)	(0.06)	(0.02)
QE	0.07***	0.10***	0.02
	(0.01)	(0.02)	(0.05)
Observations	218	53	27
R-squared	0.33	0.58	0.27

Note: The table reports the reaction of the euro-dollar exchange rate over different samples to surprises in monetary policy using intraday data. Coefficients are expressed in percentage points per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

5.2.3 Sovereign Yield Responses

In this section we will analyze the effects from the four factors, namely, Target, Timing, Forward Guidance and QE, on Italian and Spanish sovereign yields. Similarly, as Altavilla et al. (2019), we do not report effects on German and French sovereign yields as effects on German yields are very similar to OIS rates and French sovereign yields are closely linked to the German yields.

As evident in Table 5.6 and Table 5.7, the Target factor generally shows insignificant coefficients for Italian and Spanish sovereign yields across most subsamples. The notable exception is the significant coefficient for the 2-year Spanish sovereign yields during the 2014-2020 period. This suggests that, except for this specific instance, sovereign yields at with maturities of two years or more are not highly responsive to changes in the policy rate. This aligns with the observations of the Target factor mainly affecting the shortest OIS yields, as depicted in Tables 5.2–5.4

The Timing factor indicates significant responses for both Italian and Spanish 2- and 5-year sovereign yields in the 2014-2020 period and for 2-, 5-, and 10-year yields for the full sample period. However, this factor does not show significant responses in the 2020-2023 subsample. This can indicate that market reactions to timing aspects of policy announcements have been more pronounced in certain periods but were not significant during the pandemic and the following years.

The Forward Guidance factor remains consistently significant across all periods, including the 2020-2023 subsample, suggesting a consistent response of yields to forward guidance irrespective of the time frame. This is in line with the results presented by Altavilla et al. (2019).

The QE factor has a more pronounced and significant effect on Spanish sovereign yields compared to Italian yields for the full sample period. Particularly, Spanish Sovereign 5- and 10-year yields show significant responsiveness to QE across all subsamples. For Italian yields, significant coefficients are found for the full sample and the 2014-2020 subsample, but not for the 2020-2023 subsample. This highlights the differentiated impact of QE on the sovereign yields of these two countries.

The QE factor had a larger effect on the sovereign yields of Spain and Italy than on the OIS yields in the subsample 2014-2020. This matters especially for the Italian 10-year yields compared to the 10-year OIS yields.

The factors in the press release and press conference windows affect the sovereign yields of Italy and Spain similarly to how they affect the risk-free yields, represented by the OIS yields, at the same maturities. This indicates a parallel movement of sovereign yields with risk-free rates in response to monetary policy factors.

Table 5.6: Estimated effects of monetary policy surprises on Italian sovereign yields

	Jan-02/Jun-23			Jan-14/Jan-20			Feb-20/Jun-23		
VARIABLES	IT 2Y	IT 5Y	IT 10Y	IT 2Y	IT 5Y	IT 10Y	IT 2Y	IT 5Y	IT 10Y
Panel (A): Press release window									
Target	0.15	0.10	0.03	0.63	0.37	0.16	-0.16	-0.18	-0.12
	(0.19)	(0.17)	(0.13)	(0.52)	(0.61)	(0.78)	(0.29)	(0.29)	(0.28)
Observations	223	223	223	53	53	53	27	27	27
R-squared	0.01	0.01	0.00	0.06	0.02	0.00	0.01	0.01	0.01
Panel (B): Conference window									
Timing	0.70***	0.42***	0.28**	1.10**	1.13**	0.76	-0.03	-0.23	-0.57
	(0.15)	(0.16)	(0.11)	(0.42)	(0.48)	(0.46)	(1.55)	(1.77)	(1.64)
FG	0.96***	0.81***	0.47***	1.01***	0.88***	0.84**	0.96***	0.97***	0.84***
	(0.07)	(0.08)	(0.07)	(0.25)	(0.31)	(0.36)	(0.20)	(0.27)	(0.28)
QE	0.14	0.34	0.61*	0.66***	0.89***	1.56***	-0.41	-0.58	-0.19
	(0.21)	(0.30)	(0.35)	(0.15)	(0.21)	(0.20)	(0.59)	(0.78)	(0.82)
Observations	218	218	218	53	53	53	27	27	27
R-squared	0.46	0.28	0.17	0.58	0.52	0.68	0.34	0.24	0.20

Note: The table reports the reaction of Italian sovereign yields at different maturities to surprises in monetary policy using intraday data. Coefficients are expressed in percentage points per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 5.7: Estimated effects of monetary policy surprises on Spanish sovereign yields

	Jan-02/Jun-23			Jan-14/Jan-20			Feb-20/Jun-23		
VARIABLES	ES 2Y	ES 5Y	ES 10Y	ES 2Y	ES 5Y	ES 10Y	ES 2Y	ES 5Y	ES 10Y
Panel (A): Press release window									
Target	0.19	0.06	0.06	0.87***	0.60	0.62	-0.08	-0.23	-0.19
	(0.11)	(0.14)	(0.13)	(0.21)	(0.39)	(0.49)	(0.11)	(0.20)	(0.18)
Observations	223	223	223	53	53	53	27	27	27
R-squared	0.05	0.00	0.00	0.58	0.15	0.09	0.01	0.04	0.03
Panel (B): Conference window									
Timing	0.69***	0.49***	0.28***	0.77**	1.15***	0.53	1.65	0.91	0.48
	(0.10)	(0.11)	(0.09)	(0.31)	(0.41)	(0.39)	(1.07)	(0.78)	(0.82)
FG	0.83***	0.79***	0.46***	0.48**	0.89***	0.66**	0.80***	0.93***	0.67***
	(0.06)	(0.05)	(0.06)	(0.24)	(0.23)	(0.32)	(0.09)	(0.09)	(0.15)
QE	0.18	0.49**	0.70**	0.44***	0.71***	1.33***	-0.07	0.59**	0.70*
	(0.13)	(0.20)	(0.27)	(0.10)	(0.11)	(0.14)	(0.27)	(0.23)	(0.34)
Observations	218	218	218	53	53	53	27	27	27
R-squared	0.56	0.47	0.27	0.56	0.67	0.75	0.57	0.75	0.54

Note: The table reports the reaction of Spanish sovereign yields at different maturities to surprises in monetary policy using intraday data. Coefficients are expressed in percentage points per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

5.2.4 Stock Market Responses

Table 5.8 present the intraday reaction of the euro area stock market, as represented by the Euro Stoxx 50 and the Euro Area Bank Stock Market Sub-Index (SX7E), to our identified monetary policy surprises.

Similar to Altavilla et al. (2019), we find statistically significant and negative reactions for the Target factor in some of the given subsamples. This implies that surprises leading to increased yields, e.g., positive interest rate surprises, tend to result in declines in stock indices. This is in line with the literature on monetary policy, where it is commonly agreed that changes in the policy rate can have a negative impact on the stock market. When the central bank raises the policy rates, the stock market often faces challenges, as it elevates borrowing costs, reducing available funds for companies to reinvest and impacting cash flow stability. This, in turn, exerts downward pressure on share prices. Moreover, higher interest rates lead to an increased discount rate, negatively influencing the present value of future income. Conversely, when interest rates decline, the opposite dynamics come into play. Lower interest rates generally have a positive impact on earnings and stock prices, with the exception of the financial sector. (Rangvid, 2021).

When exploring stock price behaviors during the press release window, a pronounced negative impact of the Target factor on the euro area stock market index (STOXX50E) is evident across the entire sample. For the discussions within the conference window, significant negative effects are attributable to the Timing factor for both the general and banking sector indices (STOXX50E and SX7E, respectively) during the 2014-2020 span.

The Forward Guidance factor exhibits comparable negative influences on the STOXX50E for all observed periods and on the SX7E during the 2014-2020 timeframe. Looking at this factor in the 2020-2023 sample period, given the historically low interest rates, the significance of the factor might reflect the market's sensitivity to signals hinting at a policy shift leading to interest rate increases. The low-interest rates have been a key element of monetary policy to bolster economic activity during the pandemic. Any indications of tightening during the onset of the inflationary period could have disproportionately influenced market expectations.

For the period from 2020 to 2023, we observe that the Quantitative Easing factor elicits significant positive responses for both indices.

Table 5.8: Estimated effects of monetary policy surprises on stock prices

VARIABLES	(2002-2023) **STOXX50E**	(2014-2020) **STOXX50E**	(2020-2023) **STOXX50E**	(2002-2023) **SX7E**	(2014-2020) **SX7E**	(2020-2023) **SX7E**
Panel A: Press release window						
Target	-0.03**	-0.04	-0.03	-0.02	0.06	-0.01
	(0.02)	(0.08)	(0.03)	(0.02)	(0.13)	(0.04)
Observations	223	53	27	223	53	27
R-squared	0.07	0.02	0.06	0.01	0.01	0.01
Panel B: Conference window						
Timing	0.00	-0.23**	-0.04	0.01	-0.32**	0.02
	(0.02)	(0.11)	(0.09)	(0.03)	(0.13)	(0.22)
FG	-0.03*	-0.21***	-0.08**	-0.03	-0.24**	-0.01
	(0.01)	(0.08)	(0.04)	(0.02)	(0.10)	(0.05)
QE	0.00	-0.06	0.11**	0.12*	0.05	0.35**
	(0.03)	(0.04)	(0.05)	(0.06)	(0.08)	(0.13)
Observations	218	53	27	218	53	27
R-squared	0.03	0.30	0.26	0.06	0.10	0.30

Note: The table shows the reaction of the general euro area stock market index (STOXX50E) and the euro area bank stock market sub-index (SX7E) over different samples to surprises in monetary policy using intraday data. Coefficients are expressed in percentage points per standard deviation change in the factors. Robust standard errors in parentheses; ***,**,and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

This period has been significantly influenced by the Covid-19 pandemic, resulting in unprecedented economic turmoil. The monetary policy surprises during this timeframe, particularly the responses related to QE, could be tied to the extensive fiscal and monetary measures implemented to alleviate the economic fallout. Quantitative easing, essentially equivalent to the injection of new money into the economy according to the European Parliament (2015), may explain the positive effects observed on STOXX50E and SX7E during this sample period. The European Parliament (2015) states that the underlying hope is that entities selling bonds to the ECB and receiving money are expected to channel this influx into riskier ventures or spending on goods and services. If this scenario unfolds, it logically aligns with the positive impact observed on both stock indexes, as it would stimulate economic activity and encourage investment in assets.

Similar responses are found by Altavilla et al. (2019) for the Target factor in their full sample, concluding in 2018, and in the pre-2008 crisis sample. Regarding the Timing and Forward Guidance factors, they report similar responses also for the post-2014 sample. In contrast to our findings, they do not observe significant responses for the Quantitative Easing factor. This could be attributed to the already low-interest rates diminishing the marginal effect of additional QE or due to market concerns about the potential for inflationary pressures resulting from sustained QE (Beck et al., 2019).

5.3 Information Effects

This discussion concerning the interpretation and realization of monetary policy surprises by markets raises a crucial issue highlighted in the study by Altavilla et al. (2019). This topic is extensively discussed in recent literature, including works by Nakamura and Steinsson (2018b), Miranda-Agrippino and Ricco (2021), and Andrade and Ferroni (2021). The concept explored is that market participants can interpret any type of monetary decision or signaling in two distinct ways: either as a disclosure of future monetary policy moves, also referred to as an *Odyssean surprise*, or as a revelation of information about the future state of the economy, known as an *information shock* or *Delphic surprise*.

The impact of unexpected policy moves on the economy can vary, as demonstrated by studies such as Andrade and Ferroni (2021). Odyssean and Delphic policy surprises, even though the effect on the yield curve is in the same direction, can have opposing effects on the stock market, potentially canceling each other out and resulting in no clear overall impact. This might explain why some of the reactions presented in Table 5.8 are not significant on average.

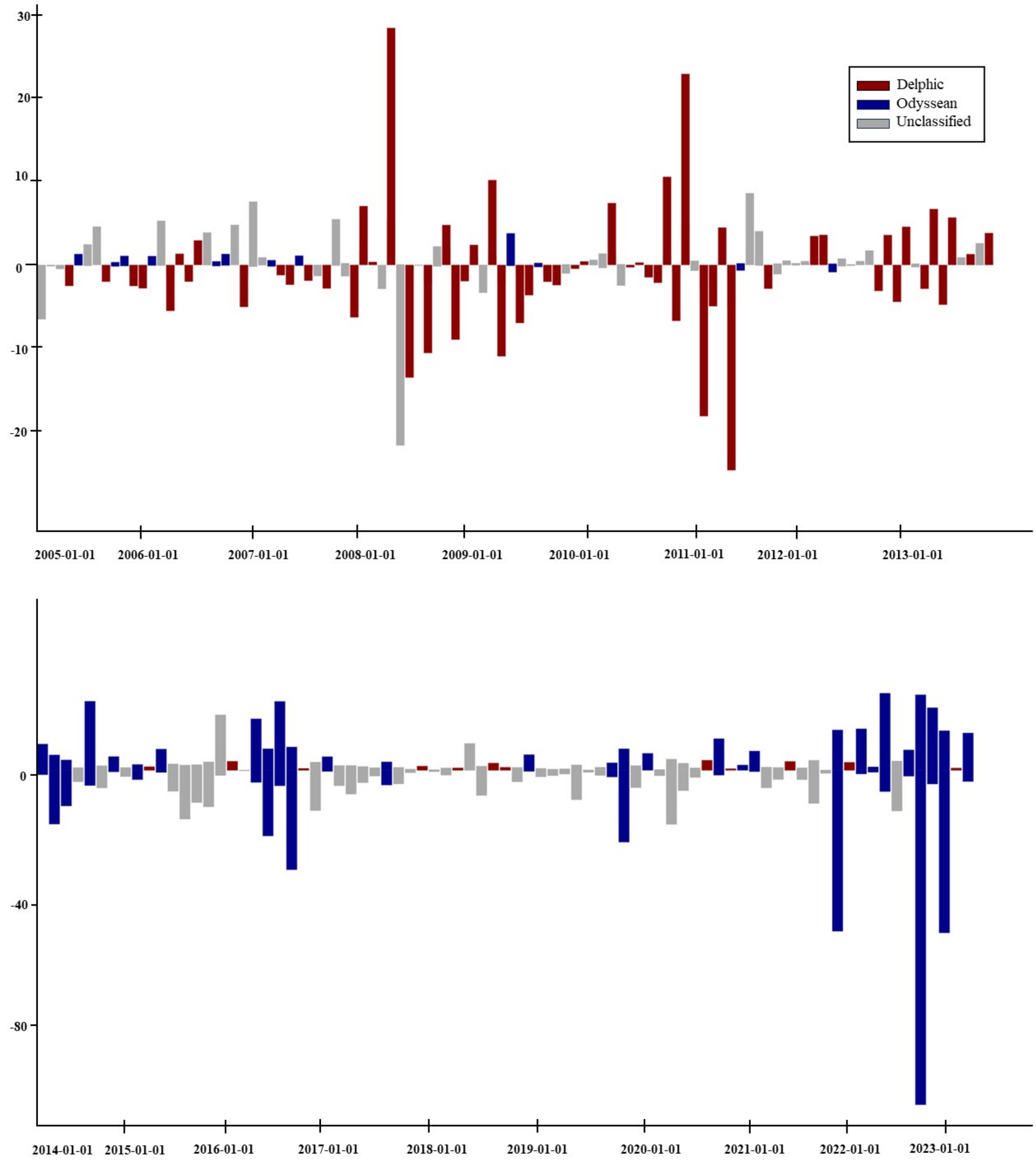
As emphasized by Altavilla et al. (2019), these two types of surprises, Odyssean and Delphic, exert opposite effects on stock index yields. Higher interest rates are generally considered unfavorable for the stock market due to increased borrowing costs and reduced consumer spending. However, if higher rates indicate an economy that is doing better than initially expected, it could be perceived as positive news, potentially leading to higher profits for companies and their shareholders. Therefore, when Delphic surprises occur, reactions might not be statistically significant on average.

Just like with interest rates, expectations of inflation can also be influenced by monetary policy. Generally, when there is a surprise interest rate cut people might initially expect an increase in inflation, but if they interpret the surprise cut as a signal of low inflationary pressure, their expectations may shift towards anticipating a decrease in inflation.

To determine evidence of both types of surprises, we follow the methodology of Altavilla et al. (2019), comparing the sign of the response of the stock market and inflation-linked swaps (ILS) for each policy event. If stock prices and ILS, which literature suggests should move in the opposite direction to nominal rates (Rangvid, 2021), move in the same direction as policy rates, it suggests the prevalence of information shocks. If stock prices and ILS move in the opposite direction of nominal interest rates, it suggests that there are no information shocks from the monetary policy.

Applying the identification methodology described in Section 4.2.1 we assess the response of 2-year OIS rates, 2-year euro area ILS, and the daily logarithmic changes in stock market prices as measured by the STOXX50E Index to the identified factors. This involves examining the predicted one-day variation surrounding policy announcements. As we mentioned in Section 4.2.1, we compute the daily and not the intraday variation around policy events due to the limitations of obtaining data for ILS at the intraday level.

Figure 5.4: Information and monetary policy surprises around ECB meetings



Note: The figure shows the changes in 2-year OIS on ECB Governing Council Policy Meeting Dates in the pre- and post-QE periods in the first and second panel respectively. Days in which the 2-year OIS, log STOXX50E, and 2-year Inflation-linked swap variables comove (red bars) have predominantly information surprises (Delphic), while days in which bond yields move in the opposite direction of the other two (blue bars) have predominantly pure monetary policy surprises (Odyssean). Grey bars represent the other cases (Unclassified). Data used for plotting the figures has been retrieved from Bloomberg and Thomson Reuters

Figure 5.4 illustrates the instances where stock prices, inflation-linked swaps, and OIS rates move harmoniously, depicted in red[9]. These occurrences signify market interpretations of policy as Delphic (information-based) surprises. Conversely, blue bars denote pure Odyssean (policy-driven) surprises, characterized by divergent movements in ILS, logarithmic changes in the stock market, and OIS rates. The magnitude of these bars corresponds to the intensity of the market's response to these policy surprises. Notably, these fluctuations often align with periods of heightened uncertainty or crises, as seen during the 2008 financial crisis, the subsequent Eurozone crisis, and more recently, the period marked by significant interest rate hikes in response to soaring inflation.

Furthermore, Figure 5.4 reveals a substantial variation in how market participants interpret policy surprises across different subsamples. In the post-2014 period (illustrated in the bottom panel), occurrences of information shocks (characterized by movements in nominal interest rates, stock prices, and inflation-linked swaps in the same direction) are infrequent. In contrast, during the 2008 financial crisis (top panel), such information shocks were more prevalent. This suggests that, during the crisis, market participants placed greater emphasis on the surprises as indicators of information they believed the ECB possessed. This observation aligns with the studies of Altavilla et al. (2019) on similar phenomena, as well as Lunsford (2018)'s research on the US market.

Altavilla et al. (2019) identifies a higher prevalence of Delphic surprises during crises, such as the 2008 financial crisis. This is attributed to financial market participants assigning greater importance to these surprises, considering them as valuable information held by the ECB. Given that the Covid-19 period is also marked by crisis conditions, one might anticipate a similar prevalence of Delphic surprises. Surprisingly, our findings reveal no significant Delphic surprises during the Covid-19 period and its aftermath.

The absence of notable Delphic surprises during the Covid-19 crisis could be related with the findings of Bauer and Swanson (2023a). Their research suggests limited evidence of information effects from FOMC announcements. However, they acknowledge the potential for information effects in exceptional circumstances, implying that information effects are more likely to be present in times of crisis. Nevertheless, despite the pandemic being an exceptional circumstance, we do not observe significant Delphic surprises during this

[9]See Appendix A.1 for a detailed plot showing the direction of the three variables for each of the policy events

period.

Andrade and Ferroni (2021) argues that there has been a noteworthy shift in the ECB's communication strategy during the period when interest rates approached the ELB. In this period, they highlight that the ECB's communication on future interest rates became more influential through more explicit communication, i.e., forward guidance. Consequently, there was a transition from predominantly Delphic interpretation before the ECB approached the ELB to a more Odyssean interpretation afterward. The use of FG about the future stance of monetary policy has also been predominant during both the ZLB phase amid the Covid-19 pandemic and the subsequent inflation crisis. The consistent and significant role of FG over the past decade, including throughout the Covid-19 era and its aftermath, explains the absence of significant Delphic surprises in the 2020-2023 period. This continuity is observed despite this period being characterized by crisis conditions.

6 Conclusion

In this master thesis, we have examined the impact of monetary policy surprises in the Euro area on a range of crucial financial indicators, with a particular emphasis on the period from 2020 to 2023. This era, marked by the global Covid-19 pandemic, has been further complicated by a sequence of significant global events, including military conflicts, supply chain disruptions, energy crises, and escalating inflation. These challenges have significantly tested the design, implementation, and efficacy of monetary policy.

To conduct the analysis, we used the EA-MPD database, which compiles monetary policy surprises. These surprises are defined as the intraday changes in key financial variables that occur in a narrow time window around the policy announcements made by the European Central Bank's Governing Council. This approach allows for a causal interpretation of how monetary policy impacts financial markets. Furthermore, by employing these identified policy surprises, we have delved into the identification of information effects within the sample period. Unraveling these information effects is crucial for a deeper understanding of the signaling implications and the overall effectiveness of monetary policy interventions.

Our findings are, to a large extent, consistent with those of Altavilla et al. (2019), particularly in terms of the relative significance of various factors in accounting for policy surprises. However, we find marked differences for the 2020-2023 period which are worth mentioning.

In our results, the Target, FG and QE factors explain slightly more of the variance in 1-month, 2-year, and 10-year OIS rates, respectively. The Timing factor explains slightly less of the variance in the 3 and 6-month OIS rates.

Regarding the effects of monetary policy surprises on the financial variables of interest in the 2020-2023 subsample, we find somewhat surprising results. Especially the Target factor's smaller effect on OIS yields in this sample period is striking as we would expect larger effects in this period due to the many interest rate changes experienced during the period. This could thus be indicative of financial market participants anticipating interest rate changes to a slightly larger extent than before.

Furthermore, our result regarding the Timing factor is interesting. The effect of the

Timing factor on OIS rates is significantly larger in the 2020-2023 subsample compared to the 2014-2020 sample. This suggests that during the Covid-19 pandemic and the subsequent period, financial market participants adjusted their expectations regarding upcoming monetary policy decisions to a greater extent compared to previous periods. However, this is not a surprising result due to the many, and relatively large, interest rate changes we have seen during this period.

Notably, from 2020 to 2023, the Quantitative Easing factor elicited significant positive responses for the STOXX50E and SX7E indexes, reflecting the extensive fiscal and monetary expansion implemented during the Covid-19 pandemic. This period's monetary policy surprises, particularly related to QE, are believed to have positively influenced STOXX50E and SX7E by stimulating economic activity and encouraging asset investment. This proves the efficacy of unconventional monetary policy tools during crisis. This contrasts with Altavilla et al. (2019), who did not observe significant responses to the Quantitative Easing factor, possibly due to already low-interest rates or concerns about inflation from sustained QE.

Our analysis reveals that certain factors within our sample do not exhibit significant impact on stock prices, suggesting the presence of Delphic surprises. This aligns with the existing literature, including the work of Altavilla et al. (2019), indicating that the same monetary policy action can lead to opposing effects on the stock market, depending on its interpretation as an Odyssean or a Delphic surprise. This divergence is particularly evident in our observations from the STOXX50E Index, where some reactions are not statistically significant on average.

Additionally, we find persistent significance of Forward Guidance across all periods, also during the Covid-19 pandemic. This indicates that despite the crisis conditions, market participants did not predominantly interpret policy actions as conveying new information about the economic outlook (Delphic surprises) but as explicit communication about the future direction of monetary policy. This finding, in line with the results of Andrade and Ferroni (2021), is particularly striking, since it suggests the absence of significant information shocks, or Delphic surprises, during the recent tumultuous period encompassing the Covid-19 crisis. This stands in contrast to our previous expectations and other historical precedents in the literature, where crises typically intensified the prevalence of Delphic surprises.

For future research, it would be interesting to extend the analysis for the 2020-2023 period with a vector autoregression, in a similar fashion to studies by Altavilla et al. (2019), Baumgärtner (2020), and Andrade and Ferroni (2021), which incorporate the identified policy surprises as external instruments in the model. We have refrained from doing this due to the scope and time constraints of our study. This would allow a more in-depth exploration of information effects and the role of uncertainty in monetary policy, enriching the understanding of these dynamics.

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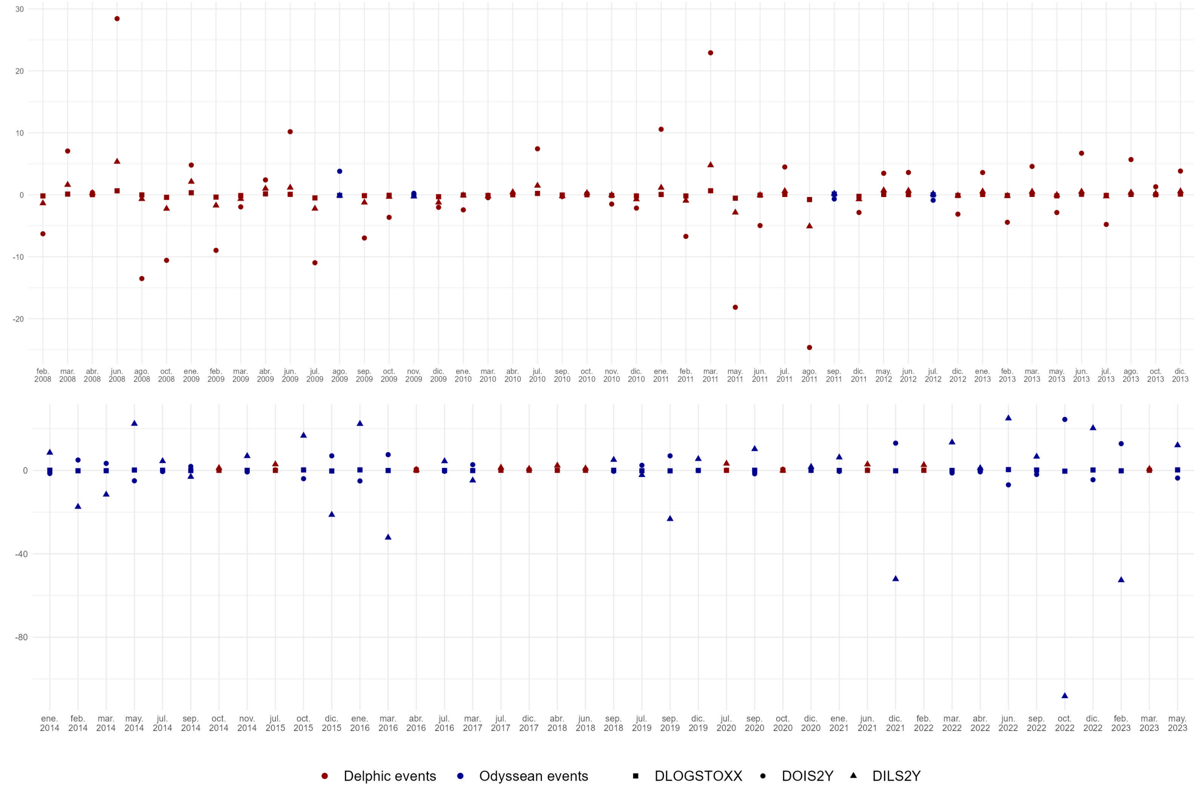
Appendices

A Figures

Figure A.1: Information and monetary policy surprises around ECB meetings: scatter plot



Note: : The figure shows the changes in 2-year OIS on ECB Governing Council Policy Meeting Dates in the pre- and post-QE periods in the first and second panel respectively. Days in which the 2-year OIS, log STOXX50E, and 2-year Inflation-linked swap variables comove (red bars) have predominantly information surprises (Delphic), while days in which bond yields move in the opposite direction of the other two (blue bars) have predominantly pure monetary policy surprises (Odyssean). Grey bars represent the other cases (Unclassified). Data used for plotting the figures has been retrieved from Bloomberg and Thomson Reuters